Sky and TELESCOPE

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Coronagraph observatory

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In This Issue:

Some Instruments for Solar Research

Eclipse Observing Information

The Meaning of Stellar Evolution

Northern and Southern Star Charts

Sky and TELESCOPE

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Palomar Observatory

THE National Academy of Sciences has released the text of a lecture by Dr. I. S. Bowen, director of Mount Wilson and Palomar Observatories, delivered on April 23rd, at the annual meeting of the academy in Washington, D. C.

Dr. Bowen devoted the first portion of his talk to a review of the development of the telescope, pointing out how the refractor and reflector alternated in popularity over long periods. He told how George Ellery Hale adopted the policy that the 200-inch telescope should not merely be a double-sized 100-inch, but that every effort should be made to introduce new methods and new auxiliary equipment. One of the processes developed in the course of studies for the 200-inch was that of evaporating aluminum on glass, a process now almost universally used.

"One of the very difficult problems was the elimination of the effects of flexure of the telescope tube," Dr. Bowen said. "Thus, a concave mirror of as short a focal ratio as f/3.3 has a field of view of good definition only about one-half inch in diameter. One of the projects undertaken with the 200-inch construction funds was the development of lenses to be mounted in front of the photographic plate to increase the size of the field of good definition to a diameter of several inches. Such lenses were successfully designed by Dr. F. E. Ross. Unfortunately, for proper operation of these lenses it is necessary that their axis must maintain coincidence with the axis of the main mirror in all positions of the telescope."

The 200-inch tube is 55 feet long, with the mirror and its mounting weighing over 30 tons at one end and the observer's cage with the photographic plate and corrector lens at the other end. "While complete elimination of flexure is impossible," Dr. Bowen said, "the present tube was so designed that as the tube is tipped from the vertical to the horizontal the mirror and cage shift sidewise parallel to each other and by the same amount, thereby maintaining coincidence of the optic axes of the main mirror and the corrector lens. Recent optical tests have shown that this design was so successful that in no position of the telescope does the intersection of the optic axis of the main mirror with the corrector lens depart by as much as 0.01 inch from its mean position."

The final tests of the mirror in the optical laboratory in Pasadena had indicated that the outer edge was too high by 20 millionths of an inch. These tests, however, were made with the mirror on edge and its axis horizontal, and it was expected that when the mirror was placed in the telescope, with its axis vertical and the outer edge extending some 10 to 20 inches beyond the outer row of supports, it might deform downward. But the raised edge persisted in all orientations of the instrument, and the mirror was removed from the telescope in May, 1949, for refiguring. "While the actual polishing time required for the removal of this edge was only seven hours, about five months were required for the tests to determine the amount of error remaining after each period of polishing." Thereafter, regularly scheduled observations with the 200-inch telescope began on November 12, 1949.

Two Ross corrector lenses are among the accessories used regularly, and several spectrographs are being provided, described by Dr. Bowen as follows:

"These spectrographs range from very low-dispersion instruments of extreme speed for the analysis of the light of a nebula hundreds of millions of light-years away to long-focus high-dispersion instruments for the detailed study of the light of a bright star. Thus, the low-dispersion spectrograph spreads the light of the object under investigation into a spectrum only 1/10 inch long, but uses a camera of extreme speed operating at a focal ratio of slightly less than f/0.5. At the other extreme is the large coude spectrograph. As a dispersing unit, this spectrograph has a composite grating made up of four large gratings, each with a ruled surface 5½ x 7 inches, mounted to handle a beam of light 12 inches in diameter. Five cameras having focal lengths ranging from eight inches to 12 feet and operating at focal ratios from f/0.7 to f/12 are provided to give dispersions up to 2.3 angstroms per millimeter. This is nearly half the dispersion used by Rowland in his classical studies of the solar spectrum, yet it is feasible with the present instrument to photograph at this dispersion the spectrum of an 8th-magnitude star, that is, two mag-

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COVER: A sketch of the turret and enclosure for the large coronagraph to be erected at the new Chalk Mountain station of the High Altitude Observatory. The cone-shaped dome, designed to shed heavy winter snows, reaches 45 feet above ground level. The room beneath the turret has a diameter of just over 50 feet, and the adjoining spectrographic laboratories extend to a total length of 128 feet. (See page 187.)

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BACK COVER: The globular cluster M5, NGC 5904, photographed with the 200-inch telescope at Palomar Observatory. It is located in Serpens, at R.A. 15h 16m.0, Dec. +02° 16′; its angular diameter is 19′.9; integrated photographic magnitude, 7.04; radial velocity, 45 kilometers per second recession; distance, about 10,000 parsecs. Mount Wilson and Palomar Observatories photograph.

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Some Instruments for Solar Research

By Donald H. Menzel, *Harvard College Observatory*

Interest in the effects of solar activity on the earth has rapidly increased during the past five years. New and extensive projects for extending our knowledge about the sun are under way. Now under construction are two of the world's largest coronagraphs, perhaps the most powerful tools yet devised for solar studies. Plans call for installation of one of these instruments at the High Altitude Observatory of Harvard University and the University of Colorado, at Climax, Colo. The other will be at a companion station located on Sacramento Peak, near Alamogordo, N. M. Two instruments of this type are a minimum if scientists are to approach the desirable goal of getting at least one set of basic observations each day. Our records indicate that the unavoidable seasons of bad weather do not tend to occur simultaneously at the two locations.

Studies made during World War II show clearly that solar activity exerts a powerful influence on radio communication. Disturbances of several varieties occur in the earth's upper atmosphere as the result of solar explosions which bathe the earth in an unaccustomed glow of ultraviolet light or spray it with a shower of atoms ejected during the outburst. The term "solar explosion" is intended to be roughly descriptive of certain types of solar activity, but the exact nature of the solar disturbances is not fully understood. Hence the imperative need for further study of the phenomena.

Special instruments now patrol solar activity during the daylight hours and record the changes of this activity. Records taken with a coronagraph depict day-to-day changes in the characteristics of the sun's corona, the sun's outer envelope, whose light is so weak that observations of its features, prior to the invention of the coronagraph, were limited to total solar eclipses.

Coronagraphs, fitted with highly sensitive filters, also patrol the prominences, the great masses of gas that shine spectacularly around the limb of the sun. Occasional jets of hot luminous material rocket upward to heights in excess of a quarter of a million miles, there to fade or to splash back on the solar surface after a momentary pause. These surges resemble giant geysers. Their diameters may be 10,000 miles or more. Occasionally, one of these astounding clouds will inflate a mushroom-like cap at the peak of ascent, thus resembling, on a gigantic scale, the atomic bomb.

Motion picture records, taken with a coronagraph, confirm earlier records made by a different technique at the McMath-Hulbert Observatory, that for each ton of material seen to rise in the solar atmosphere at least 10 tons appear to fall. This observation in no way signifies that the sun is growing or picking up excess matter from interstellar space. After all, we are accustomed to see rain falling *down*, not *up*. The solar material, like rain, must rise in a form different from that in which it falls. Our observations are of luminous hydrogen, which comprises by far the greater bulk of the solar atmosphere. Some 90 per cent of the sun's atmosphere is hydrogen.

Hydrogen gas, to glow as brilliantly as it does in the solar prominences, must have a temperature of between 10,000 and 50,000° C. At lower temperatures, practically all of the hydrogen is unexcited and unable to radiate. When the temperature exceeds 10,000° C., hydrogen's sole electron, which it must possess in order to radiate, tends to become detached; the gas becomes ionized. At temperatures above 150,000° C., the detachment becomes so complete for all the atoms that the hydrogen gas practically ceases to shine.

The condition of the solar corona indicates to us that the rising gases are hot rather than cool, hotter even than the 150,000° C. stated above. Indeed, certain radiations from the corona come from iron, nickel, and calcium atoms that have lost up to half their normal component of outer electrons — a condition that could exist only if the coronal gas has a temperature well in excess of 1,000,000° C.

But where do the gases rise thus invisibly? Coronagraph observations made by Walter O. Roberts, of the High Altitude Observatory, indicate the presence of a zone of boiling, bubbling activity near the two poles about which the sun turns on its axis. Large mountains of gas develop with astonishing rapidity in the course of two or three minutes. When one of these attains a peak altitude of 10,000 miles or so, it seems to explode and eject a luminous core that shoots out into space from the surface of the sun, fading as it rises.

These moving filaments, usually called spicules, raise several important problems. What forces give rise to their motions? Where does the matter go as it fades away to invisibility? Does it, perhaps, go to maintain the filaments of the solar corona whose polar streamers often form so conspicuous a pattern of the eclipse photographs? Some observations indicate that the corona and spicules are thus intimately related.

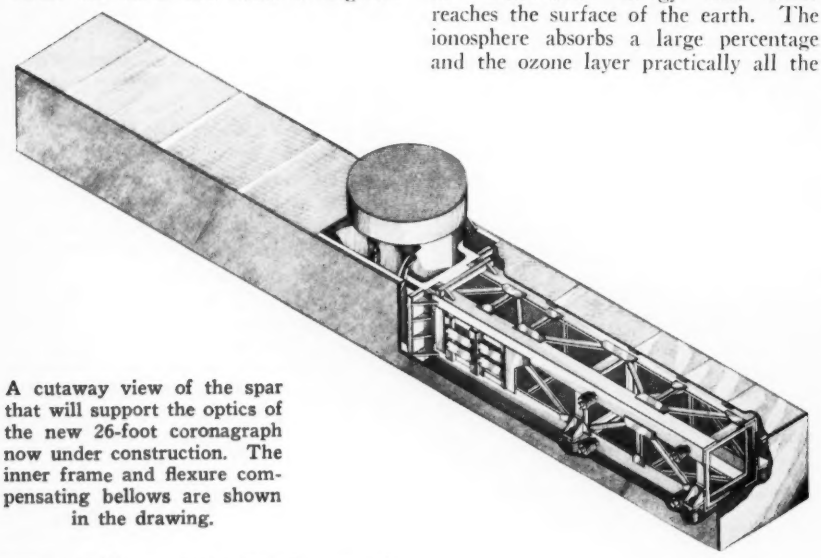
A theoretical study leads us to conclude that magnetism may be as important as gravity in controlling the motions of gases in the solar atmosphere. The invisible lines of magnetic force act like soft springs. They sag under the weight of the solar prominences, but tend to provide support because the gases tend to "stick" to the lines of force.

Our knowledge of solar activity is still far from complete. However, a model that explains some of its major features provides a tentative basis for still more tentative calculations. According to this picture, the bubbling spicules near the poles assume special importance. We still do not understand why the sun spurts forth these knots and lumps of hot gas. However, the mag-

The Chalk Mountain site, with a residence at the left and two Quonsets at the right. This is four miles northwest of the original Climax coronagraph.

netic force lines act as a focusing device. First, they keep the clouds from dispersing completely and, second, they may even recompress a partially expanded cloud as it descends toward the surface of the sun.

Occasional clouds, perhaps expelled more energetically than usual, may even strike the earth and cause a magnetic storm, with marked disturbances of the compass needle. Also, as atoms from the sun meet atoms of the earth in the highly rarefied upper atmosphere, the collisions produce the aurora borealis.



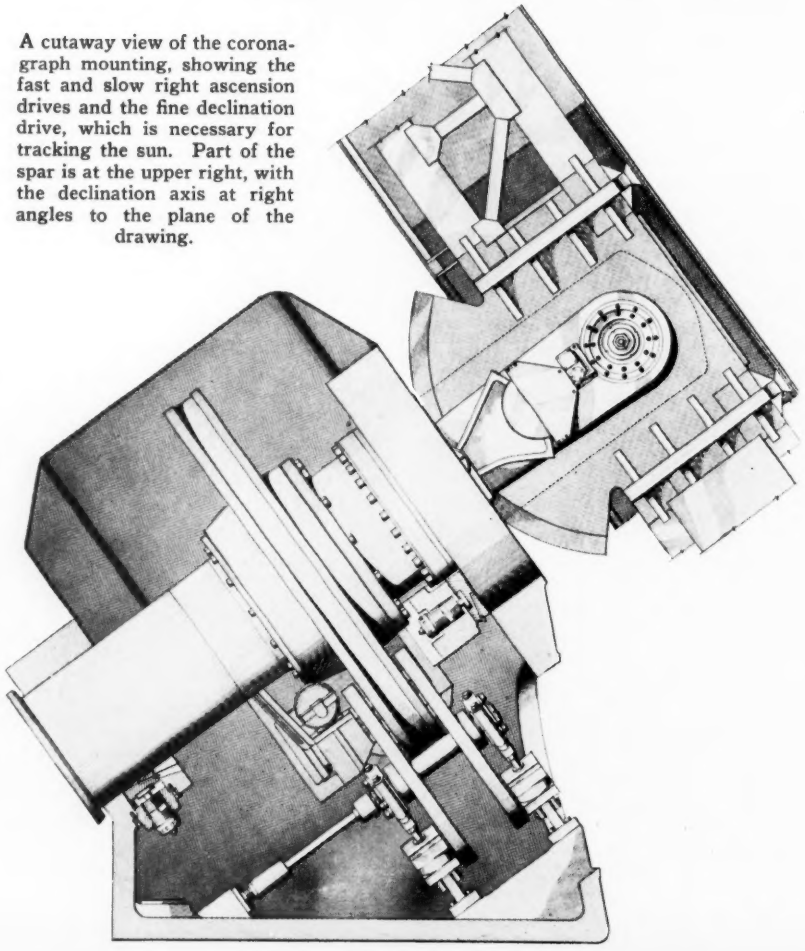
A cutaway view of the spar that will support the optics of the new 26-foot coronagraph now under construction. The inner frame and flexure compensating bellows are shown in the drawing.

Some of the ejected material, cascading back to the sun, forms the prominences. The flowing gases warp and twist the magnetic lines of force. Occasional lumps compress so rapidly that the hydrogen nuclei suddenly find themselves once again close to electrons. The recombination of these bodies releases a blast of ultraviolet light that may produce further disturbances when it reaches the earth's atmosphere. These disturbances include the aforementioned effects on radio communication. Associated with the solar flares, as we term the bright explosions, is a raucous rattle of high-frequency radio noise sent out by the sun. The nature of this solar static, which occasionally reaches an intensity sufficient to interfere with radar and television services, is not fully understood. One objective of the current solar studies is the understanding of mechanisms whereby the sun radiates this static. Records of the changing formations on or above the solar surface, when checked against records of the outburst of solar noise over the same period, may well disclose the character of the relationship. Such simultaneous studies are an integral part of the program of solar observations.

Study of the sun and of its terrestrial effects should have a far-reaching influence on a variety of sciences, especially those closely related to the upper atmosphere. Temperatures and pressures in the levels far above the stratosphere should and probably do vary with solar activity. The rarefied gases of high altitudes should be far more sensitive than the denser gases of the troposphere to fluctuations of solar heat. Most of the changes of solar radiation occur in the far ultraviolet — energy that never reaches the surface of the earth. The ionosphere absorbs a large percentage and the ozone layer practically all the rest of the solar ultraviolet radiation.

Whether or not variable solar activity can influence weather at the earth's surface is a question that scientists have debated for many years. Perhaps the most convincing evidence for a connection between the two phenomena lies in the fluctuating widths of tree rings. The total annual growth must in some way be a gauge for the average weather conditions, a complicated sort of average compounded of total sunshine, effective rainfall, and mean temperatures. As A. E. Douglass has shown, the tree-ring patterns, especially in certain areas of the world, appear to be sensitive to the solar variation and to reflect the 11-year sunspot cycle in the banded structure of the rings.

As a further check on such relationships, Richard A. Craig, working at Harvard, has carefully examined the shifting world-wide pattern of atmospheric pressure. He finds highly significant relationships between recorded magnetic disturbances (whose solar origin we cannot doubt) and the aforementioned pressure pattern. The probability that such relationships might occur by pure chance is practically negligible. Craig's work, when extended, gives promise of greatly improving our



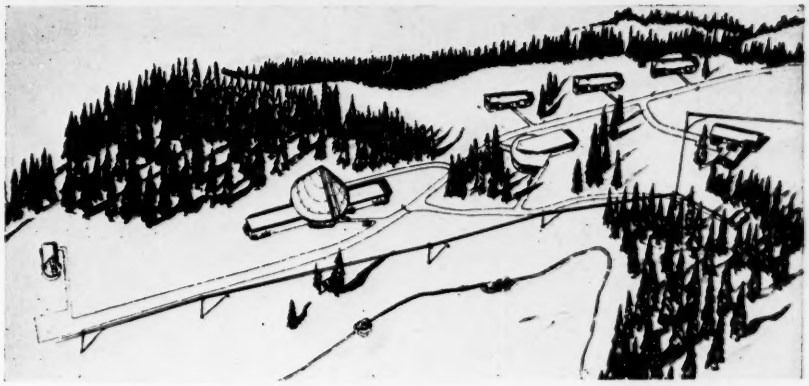
A cutaway view of the coronagraph mounting, showing the fast and slow right ascension drives and the fine declination drive, which is necessary for tracking the sun. Part of the spar is at the upper right, with the declination axis at right angles to the plane of the drawing.

procedures for long-range weather forecasting.

One of the objectives of this large-scale, long-range program of research is the prediction of solar activity itself. For, if we can solve the basic problems of the sun-earth interaction and really understand what is going on in the solar atmosphere, ability to forecast solar activity implies also ability to predict the terrestrial disturbances. Indeed, we look forward to the time when we can give improved forecasts of the ultraviolet blasts that often interfere with and occasionally completely disrupt radio communications. Can we discern in the changing patterns of sunspots, prominences, corona, and spicules the underlying causes that produce and control these solar features?

Perhaps, then, we shall also be able to predict when the earth will run into one of those blasts of solar atoms — blasts that are sometimes sufficiently intense to shatter the ionospheric "mirror" that ordinarily reflects radio waves around the curvature of the earth. Then, too, we shall be able to forecast magnetic disturbances and the occurrence of the brilliant northern lights. The telephone linesman in the field or the engineer in a power company will benefit by the forecasts. Magnetic disturbances often produce large unwanted surges of electrical power in land lines, surges that may cause relay chatter, blow fuses, or make teletypes tick out ghost messages in unintelligible jargon. Thus, our ability to make such predictions has economic value in many fields.

Recent support for the solar research programs has come to a large extent from government sources, though various individuals, companies, or foundations have contributed. The Air Force has borne the entire expense of the program of research and development for Sacramento Peak, under Air Force Contract No. W19-122 ac-17. The chief instrument there will be a 16-inch coronagraph of very advanced design, with a wide variety of auxiliary apparatus.



The plan for Chalk Mountain includes a patrol coronagraph building (left); the main coronagraph shown on the front cover; an office and laboratory; three single-family houses (upper right); and a small cosmic-ray laboratory (right).

Support for the original Harvard Climax station came largely from individuals, with the help of many Colorado firms, chief of which was the Climax Molybdenum Company, and a number of its directors. The Dow Chemical Company assisted in the construction of the original coronagraph.

Since 1946, the Central Radio Propagation Laboratory of the National Bureau of Standards has supported work at Climax, in return for data relevant to the prediction of radio disturbances. The projected move of this laboratory to Boulder, Colo., will increase the contact between the two institutions, especially since the operating and research headquarters for the High Altitude Observatory are also now at Boulder.

The Office of Naval Research has made a grant to the High Altitude Observatory for the construction of a duplicate 16-inch coronagraph. Thus far, the turret and enclosure needed to protect this instrument from the weather are not available. The estimated cost of the needed building, sketched on the front cover, is of the order of $250,000. Other buildings to furnish offices and laboratory space and living quarters are less urgent, and temporary housing now on the new Climax site will be adequate, though somewhat primitive, until a donor who will complete the project appears.

Special assistance for a new patrol coronagraph and miscellaneous items of auxiliary equipment at Climax has come from the Research Corporation. The Boettcher Foundation has made a generous gift, and the American Academy of Arts and Sciences has provided funds for two important monochromatic filters.

TERMINOLOGY TALKS- J. Hugh Pruett

Tropical Year

This is our common year. It is also known as the solar year, the equinoctial year, and the year of the seasons. In previous Talks we explained the equinoxes: the crossings at two places in the sky of the ecliptic (the apparent path of the sun among the stars) and the celestial equator. It is known that the equinoxes move *westward* among the stars 50.3 seconds of arc annually. Thus the sun, in its seeming annual trip *eastward* among the stars, will meet the vernal equinox 20 minutes 24 seconds sooner than it will reach the point on the ecliptic where this equinox was located a year earlier. The tropical year is therefore shorter than the sidereal year by this amount, its length being $365^d\ 5^h\ 48^m\ 46^s$.

The tropical year, or the year of the seasons, would, if it could be strictly matched, keep the calendar always in step with the natural seasons. The equinoxes and the longest and shortest days of the year would fall on the same calendar date year after year. But since Julius Caesar's assumed year of 365¼ days is too long by about 11 minutes, these seasonal beginnings tended to come on earlier dates, or about three days earlier in 400 years. By A.D. 1582, when Pope Gregory and his astronomer Clavius decided to correct the calendar deficiency, about half a month had accumulated since Caesar's time.

The Gregorian calendar, the one now generally used, nearly corrects the earlier one by omitting three leap years out of 400 years. The century years must be divisible by 400 in order to qualify as leap years. Thus 1700, 1800, and 1900 were not leap years, but 2000 will be. The average Gregorian year is still 26 seconds too long, but this will result in an error of one day only after more than 3,000 years have passed.

In 1923, some countries in which the Eastern Orthodox Church was dominant adopted a leap-year rule which makes their year correct to within three seconds of the actual tropical year. In this system, century years are leap years only when a division by nine leaves a remainder of either two or six. This Eastern calendar will agree with the Gregorian until 2800, and there will not be an error of one day from the true tropical year until almost 30,000 years have passed.

Anomalistic Year

This is the time between two successive arrivals of the earth at the perihelion point, its nearest approach to the sun. Since this point moves eastward slightly each year, it takes the earth about five minutes longer than the si-

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NEWS NOTES

By Dorrit Hoffleit

SIXTH FLARE STAR

The star whose mass is the smallest yet determined for any visible star turns out to be a flare star, according to astronomers Peter van de Kamp and Sarah Lee Lippincott, of Sproul Observatory. The brighter star in the red dwarf double Krueger 60, 13 light-years distant in Cepheus, is of magnitude 9.8. Its companion is normally 1½ magnitudes fainter, but on July 26, 1939, for a few minutes it increased about four times in brightness, to appear of intensity equal to the primary.

That night, four good-quality plates were taken, each with four exposures. Krueger 60 B was of normal brightness until the last two-minute exposure of the third plate, which followed the preceding one by only two minutes. The four exposures on the last plate show the companion only slightly above normal. In all, Sproul Observatory has photographed this binary on 58 nights within the past 20 years, a total in excess of 500 exposures, and this is the only flare observed.

Of the six flare stars now discovered, the mass is known only for Krueger 60 B. It has one seventh the sun's mass; the primary has one fourth. Normally, the companion is of only 1/2,000 the sun's intrinsic luminosity.

SPECTROGRAPH CAMERA

In the *Journal* of the Optical Society of America, Abe Offner, of the Perkin-Elmer Corporation, and William B. Decker, of Perkins Observatory, describe an f/1.0 spectrograph camera. Its seven-element objective has longitudinal spherical aberration not exceeding 0.001 millimeter for wave lengths between 7000 and 9000 angstroms. In astronomical use several hundred angstroms can be photographed at one time on flat plates, and good definition can be obtained from 4000 to 9000 angstroms. While vignetting limits the field to about seven degrees, in light efficiency the camera is comparable to the modified Schmidt. Moreover, it is more convenient in that the glass plates used can be large enough to permit multiple exposures. The new camera design was achieved by splitting the symmetrical ball lens of Sutton and adding correcting components.

RADCLIFFE SPECTROGRAPH

Fifteen years ago the Radcliffe Observatory site at Oxford, England, was sold in order to use the proceeds to erect a new astrophysical observatory at a more favorable location. Before the war the new buildings and the mounting for the 74-inch reflector for the Radcliffe Observatory at Pretoria, South Africa, had been completed, but the large mirror itself was not ready and in operation until 1948. And even then it was not yet equipped for its major work, a radial-velocity program on some of the southernmost stars of the Milky Way.

The large spectrograph necessary has only recently been completed, and is described in *Nature* for February 3rd. To be used at the Cassegrain focus, the spectrograph consists of a 2½-inch collimating lens, of 45.4-inch focal length, and two 64-degree prisms with faces 2.6 by 5 inches. Any one of four cameras can be used to photograph the spectra, varying from focal length 4.75 inches (f/2) to 24.0 inches (f/8).

AMERICAN ASTRONOMICAL SOCIETY MEETING IN WASHINGTON

The 85th meeting of the American Astronomical Society will be held in Washington, D. C., June 20-23, as part of the commemoration of the semicentennial of the National Bureau of Standards and the centennial of the Nautical Almanac Office. Sessions for the presentation of papers will be held at the National Bureau of Standards. The U. S. Naval Observatory will hold open house for members and guests of the society during the day on the 20th, 21st, and 22nd, and in the evening on Thursday, June 21st.

Friday's program features a symposium on atomic and molecular spectra in astrophysics, with Dr. Henry Norris Russell presiding. Four papers will be given: "Recent Progress in Stellar Spectroscopy," Otto Struve, University of California; "Stellar Magnetism," H. W. Babcock, Mount Wilson and Palomar Observatories; "The Fundamental Standard of Wavelength," W. F. Meggers, National Bureau of Standards; and "Forbidden Transitions in the Spectra of Diatomic Molecules," G. Herzberg, National Research Council, Canada.

INSTITUTE OF NAVIGATION

The annual national meeting of the Institute of Navigation will be held June 28-30 at the Hotel New Yorker, New York City, and at Kings Point, N. Y. The meeting theme is "The Role of the Sciences in Navigation." Further information can be obtained from Paul Rosenberg, president of the society, at 233 Broadway, New York 7.

IN THE CURRENT JOURNALS

TESTS FOR THE COSMOLOGICAL TIME SCALE, by F. Zwicky, **Publications,** Astronomical Society of the Pacific, February, 1951. "Strenuous attempts have, of course, been made during the past twenty years to calibrate the cosmic scales of the distances as well as the absolute luminosities of extragalactic objects." Dr. Zwicky recommends applying the powerful method of "dimensionless morphology" to clusters of galaxies to push the solution.

THE TRIALS OF GALILEO, by Arthur R. Clute, **Journal,** Royal Astronomical Society of Canada, January-February, 1951. "To a proper understanding of the real matter at issue involved in these so-called trials, some knowledge of the mental outlook and of the intellectual level of Europe in that era is essential."

LONG - FOCUS PHOTOGRAPHIC ASTROMETRY, by Peter van de Kamp, **Popular Astronomy,** February and ff., 1951. "An attempt at an introduction to long-focus photographic astrometry, these articles may be of interest to the general reader, and helpful to the student in this field."

PALOMAR OBSERVATORY

(Continued from page 186)

nitudes fainter than any star visible to the naked eye. Some idea of the size of this spectrograph may be gained from the fact that one of the camera mirrors has a diameter of four feet and another of three feet."

Referring to the need for the 48-inch Schmidt telescope, Dr. Bowen pointed out that in their 30 to 40 years of operation only one to two per cent of the sky has been photographed by the 60-inch and 100-inch telescopes on Mt. Wilson. Nevertheless, the work with these instruments has set the pattern for the 200-inch program. The range of the 100-inch was so limited that only a few galaxies could be resolved into stars, too few to provide quantitative measures of distances and sizes of a very representative sample of these objects. After standardizing the scale of the nearby region of galaxies, the 200-inch and the 48-inch Schmidt will be co-ordinated in surveys of galaxy distribution throughout a sphere some two billion light-years in diameter.

Other problems include that of the expanding universe, the rotations of nearby galaxies, the motions of individual members in clusters of galaxies, and the relative motion of two galaxies in several known pairs. The chemical composition of the stars, planetary nebulae, long-period red variable stars, all are being studied.

Dr. Bowen concluded: "Judging by the history of many of the older telescopes still in active use, it is to be expected that the Hale telescope will continue as an effective instrument of research for 50 to 100 years to come. The complete story of the Palomar Observatory and its accomplishments can only be told after the labors of many generations of astronomers have been completed."

The Meaning of Stellar Evolution

By Otto Struve, *Berkeley Astronomical Department, University of California*

TWENTY YEARS ago it was fashionable for astronomers to engage in one of the spirited discussions that enlivened scientific meetings concerning the ages of the sun, the stars, and the galaxy. There was the "old guard," trained upon the classical concepts of celestial mechanics of the solar system, with its "invariable plane" and highly stable planetary orbits, who favored a very long time-scale, of the order of hundreds or even thousands of billions of years. And there were the "young Turks," impressed by such recent discoveries as the rotation of the galaxy, with its disrupting effect upon loosely bound, open galactic clusters, who insisted that the entire age of the galaxy could not be more than about three billion years.

Subsequent advances have favored the shorter time-scale. Not only would the open clusters be disrupted, and their members spread along the Milky Way in the longer time interval, but the geological determinations of the ages of terrestrial rocks and of meteorites, the processes of energy production in stars, and the phenomenon of the recession of the galaxies, all agree in their evidence — something very drastic must have happened in the universe about three billion years ago.

We do not attempt to define exactly what we mean by the "age of the galaxy" or by the "astronomical time-scale." Those primarily interested in the dynamical effects are thinking of a time interval during which stellar motions would be greatly altered by the gravitational action of other stars, with an appreciable tendency of the members of an open star cluster to diffuse among the star clouds and spiral arms of the Milky Way. A theoretical astrophysicist would think of the time required to convert into helium a large fraction of the available hydrogen content of a star's interior. And a geologist would be content if he could specify how long basic rock has existed as a separate piece of solid material, without worrying much about what went before.

Thus, when we now say that the age of our galaxy is about three billion years, we mean that three billion years ago the galaxy was, as a whole, not very different from what it is now, but that its individual building blocks, the stars, planets, clusters, nebulae, and so on, have undergone large evolutionary changes since that time. We do not know enough even to speculate constructively about what the universe was like 100 or 1,000 billion years ago. For all we know, it may have assumed its present aspect as the result of some tremendous catastrophe, like the bursting of Lemaitre's original cosmic egg, or like the disintegration of the neutron snowball suggested by Teller. Or it may have evolved gradually from some other condition, the nature of which is shrouded in darkness, and which probably will remain unknown to us for a long time to come.

Thus, our present aim is not to discuss the entire age of the galaxy, but only that part of its life during which the sun and the rest of the stars have undergone appreciable changes in their physical properties, primarily in their luminosities, masses, and radii. It is as though a historian among the butterflies were content with discovering the growth and the aging processes of his species during the butterfly stage, without attempting to consider the cocoon stage, or even whether there was a metamorphosis of successive stages before the butterflies came into being.

Three billion years is a long interval, when we realize that very accurate astronomical observations have been conducted only in the past century or two, and that the rise of astrophysics took place very largely during the last 30 years. We can hardly expect that within this minute fraction of the entire lifetime of a star we would be able to detect any real changes of an evolutionary character. Of three billion years, 30 years is only one part in 100 million. Hence, if the evolution of a star is gradual, and does not occur in sudden, catastrophic steps, we should not be able to observe any real change of an evolutionary nature.

But perhaps the nova outbursts and some of the strange phenomena among the variable stars are in reality evolutionary steps — something like the shedding of the skin of a rattlesnake that can happen a limited number of times during the life of the snake, each time leaving it older, and perhaps equipped with an extra rattle! All we can say at present is that these observed phenomena in novae and variable stars do not appreciably change the permanent mass, luminosity, and radius of such a star.

Presumably, then, it is futile to search for evolutionary changes among individual stars. All we can hope for is to try to infer what the unobserved evolutionary processes must have been during the past three billion years in order to have produced a universe having certain definite physical properties at the present time. Naturally, this is a difficult task. Suppose we observe 1,000 stars in the vicinity of the sun, in order to make certain that we have chosen a fair sample. We find that there are many small stars, the dwarfs; quite a number of very small stars, the white dwarfs; and a few very large stars, the giants and supergiants. Does that necessarily mean that the giants contract until they become dwarfs, and the latter finally end up as white dwarfs? Not at all! It is quite possible that at the beginning of our era, three billion years ago, there were already substantially the same numbers of giants, dwarfs, and white dwarfs as now. The present distribution of the observed properties, or parameters, depends upon their original distribution as well as upon their subsequent evolution.

It is quite doubtful that a final, mathematical solution exists for our problem, unless we can specify the character of the evolutionary changes, and then assume some original distribution three billion years ago, apply the evolutionary changes, and compare the resulting distribution with our present observations. If the comparison shows satisfactory agreement, we would be justified in saying that our problem has been solved. But we have no reliable theoretical knowledge of the evolutionary processes. We do have some reasonable hypotheses such as the Bethe-von Weizsaecker theory of thermonuclear conversion of hydrogen into helium. The best we can hope for now is to apply this type of reasoning, always remembering that we are dealing with a hypothesis and not with an established fact.

In order to clarify our ideas, let us discuss an "earthy" analogy to the astronomical problem, which undoubtedly has occurred to workers who have considered the matter. Suppose that an imaginary scientist on Venus succeeded in observing the earth through a small hole in the thick layer of clouds which envelops his planet almost continuously, and that with a super-telescope he recorded during an interval of half a minute of our time a large number of strange living creatures running hither and thither on two legs and all obviously belonging to the same species. If our observer were inclined to study the evolution of these beings he would quickly realize that their lifetimes greatly exceed the 30 seconds during which his observations were made. He might reason that though some of the "humans" do change in 30 seconds, in their relative positions, for example, these changes are not of evolutionary significance. He must rely upon a study of the statistical distribution of significant properties or parameters to infer what the evolution has been.

He might, perhaps, decide to measure the masses, the sizes, and the energies, mental or physical, of a sample of the

human population. In doing so he would discover that there is a large range of possible values in each of these parameters: from about five to 500 pounds in mass, from a foot or so in height to eight feet, and from a small fraction of a kilowatt to an amount of energy not much less than that of a small horse. He would also detect that not all combinations of these values are actually realized; a small human never has a large mass, nor does he have much strength. But a large specimen, though usually of considerable mass, may or may not have much energy, especially mental!

Perhaps the astronomer on Venus would attempt to construct two diagrams. In one he might plot each individual as a dot, with its mass as the abscissa and energy as the ordinate. This would give a multitude of dots, scattering slightly on both sides of a curved line, with a trend such that larger masses would usually correspond to larger energies. The line would not be exactly straight; if the ordinate represents physical energy, the curve would even show a tendency to bend over at the upper end, because very heavy persons are notably sluggish in a physical sense. This diagram would be a "mass-energy relation," corresponding to the mass-luminosity relation of the stars. The analogy is a fairly good one. Most of the humans measured by the observer on Venus would conform to the relation, but some "peculiar" individuals, though massive, would have little energy, and would form a distinct sequence, like the white dwarfs in astronomy.

Another diagram could be constructed by plotting the sizes of the human individuals against their energies. Again there would be a main sequence along which most of the points would be located. But if the observations included the Pygmies of South Africa, there might well be a separate branch. This diagram would be analogous to the Hertzsprung-Russell diagram of astronomy, or, more appropriately, to the stellar luminosity-radius diagram.

In attempting to interpret his diagrams, the astronomer on Venus would probably notice that the dots are distributed with varying frequency along his principal sequences. He would find there are a great many massive, large, and powerful individuals, and only relatively few, within a specified range, of small masses. He would not be certain how this peculiar distribution has come about, but he might venture a guess. Perhaps the human beings evolve along the main sequence, growing in size, mass, and strength, until they reach maturity. The evolutionary processes then become slower, and there is an accumulation of individuals having approximately the same parameters. He might even speak of a "sink" of fully grown persons, just as we are speaking of a "sink" of red-dwarf stars — those slowly evolving objects, like the sun or 61 Cygni, which are small and cool at the surface and do not convert much hydrogen into helium, remaining the same for billions of years.

The Venus observer would be puzzled by the fact that there are not more fully grown people on earth. Possibly his theoretical colleagues had propounded a theory of the growth of living tissue through accretion by the intake of food and its subsequent chemical assimilation. The observations might have even shown a few instances of the process of accretion in action — through the feeding of a person — and while the interpretation would be difficult and would leave the observer only partly satisfied, he might be willing to try it as a working hypothesis. In astronomy the analogy would be the accretion of interstellar material, or the reverse process, the loss of a star's substance through eruptions, rotational instability and, on a very small scale, through the radiation of light and heat.

At any rate, the observer might conclude from his working hypothesis that humans grow rapidly. He would favor a short time-scale, and if the constants of the feeding process determined by his friend, the theoretician, were correct, he would conclude that it takes only some 15 or 20 years to produce a mature man. But undoubtedly he would know that the human race must have existed much longer. A Charles Darwin on Venus would have told him that millions of

This three-dimensional model, in which the stars are represented by beads suspended on thin wires, was constructed by G. P. Kuiper to show that the least luminous stars have small masses and radii, the very luminous ones have large masses and radii. The main sequence involves all three of these characteristics, and is shown in the model by a white string along the average location of most of the stars, except the white dwarfs, which form a separate group. Yerkes Observatory photo.

years were required to produce, by natural selection, so strange an organism as man on earth. There were perhaps 10^8 small, growing creatures in the observed sample. Every 20 years or so they turn into mature men. This process has been going on for perhaps 10^7 years. Hence, there should now be on earth between 10^{13} and 10^{14} mature persons. But the "sink" contains only some 10^9. Somehow, the evolution must continue, and must remove part of the accumulation in the "sink." The diagrams give no indication of any other group into which mature men may turn — unless the observer is misled by irrelevant observations and concludes that men ultimately become insects, of which there are plenty, or elephants, of which there are not enough. He might be greatly tempted by these false conclusions, especially the latter, because it would seem to him to conform to the idea that evolution on earth means growth in mass and size, though perhaps not always in (mental) energy.

But let us suppose that through luck, or sharp reasoning, he has avoided these pitfalls. What would he then think? Mature men continue to accumulate. They are not there in sufficient numbers. Somehow, they must disappear, disappear completely from the diagram; they must undergo some sort of a sudden process — death! Thus, even without necessarily observing death or noticing its significance, the observer on Venus might nevertheless conclude that there is a sudden termination to the life spans of the creatures on earth.

It would be possible to carry our analogy still further, and find interesting parallels between what the astronomer really does when he tries to study the evolution of a star, and what a distant observer might do if he could see us for a fraction of one minute.

The principal sources of our information are the H-R diagram and the mass-luminosity diagram, which we discussed in the August, 1949, issue of *Sky and Telescope* (one illustration is reprinted here). They give us the principal sequences, with the main sequence, or dwarfs, running diagonally across both drawings. Until we knew something about the possible processes of evolution, we could only guess about the manner in which the representative point of a star might move in each diagram during three billion years.

We now know several possible evolutionary processes: nuclear transformation of the elements, loss of mass through prominence formation or through excessive rotation, gain of mass by the picking up of interstellar dust and gas; but we do not know which is the most important, or even whether they are the only processes that operate in the galaxy. We could, however, try each in succession and see what would happen to a star in three billion years. Taking the two diagrams as they are at the present time, we could then infer what they would be like that far in the future. Since, presumably, the changes in the past would be similar to those in the future, we could next modify the present diagrams by applying the computed changes with the opposite signs. This would give us an admittedly crude idea of what the galaxy was like three billion years ago. We would then ask: Is this distribution reasonable? Could we intelligently believe that the stars in the beginning of our era were distributed with regard to mass, size, and luminosity as shown by our hypothetical diagrams computed for three billion years ago?

The multiplicity of possible evolutionary processes makes it unprofitable to discuss this question seriously at the present time. There are leads, but nothing even approaching a final answer. For example, the nuclear mechanism that goes under the name of the carbon cycle has the remarkable property that, while the radius and luminosity of a star would change greatly in three billion years, its mass would change less than one per cent. Yet the observed stellar masses range from small values, probably less than 1/10 the mass of the sun, to about 50 times the mass of the sun. Hence, if the carbon cycle alone were at work, we would conclude that the stars were "born" essentially with their present masses, and that the main sequence of the H-R diagram, as well as of the mass-luminosity diagram, does not constitute an evolutionary arrangement of young stars at one end and old stars at the other.

On the other hand, we might ask: Where on these diagrams are those luminous stars that spend their energies at a prodigious rate, and convert all of their hydrogen into helium in much less than three billion years? Their masses remain nearly constant, but their luminosities increase with time; for any given mass there should be stars of vastly different luminosities.

But wait a minute! We just made an assumption without specifying it. We assumed that stars are born even now, just as children are born, so that we now observe young stars having lots of hydrogen and little helium, and old stars having little hydrogen and a great deal of helium. Can we justify this assumption? Perhaps we can, for the hottest supergiant stars, such as Rigel, exhaust their hydrogen so rapidly that we would not see them at all unless they were "born" only a short 10^7 years ago.

We come back to our question: Where in the diagrams are those older stars that 10^7 or 10^8 or 10^9 years ago were similar to Rigel now? We do not know, and the reason is not clear to us. Perhaps they are still near the main sequence, producing a scatter of values at the upper ends of both diagrams. Such a scatter is not at present indicated, but our observations of the parameters of the most luminous stars may be inadequate.

It is also possible that processes other than nuclear ones play an important role. Hoyle and Lyttleton have developed the hypothesis of mass accretion through the capture of interstellar material. Undoubtedly, this process does exist. But heretofore most astronomers were inclined to believe that the present density of the cosmic clouds of dust and gas is insufficient to produce large increases in mass. Others, notably Fessenkoff and Miss Massevich in Russia, and the present writer in this country, have explored the consequences of corpuscular radiations from the sun and stars, or loss of mass through the formation of gaseous rings in rapidly rotating objects. But still others have pointed out that there is no certainty that normal stars (that is, stars that are not novae or supernovae) lose much matter in these processes.

We must admit that there is no fully satisfactory theory of stellar evolution; and presumably many years will elapse before we have one. In the meantime we must go along the road of "multiple hypotheses," exploring each in detail. Progress is most likely to come from a systematic effort to carry each hypothesis to its (probably) bitter end. Even though we shall not know the truth, we shall in this manner accumulate experience, as well as many interesting ideas and consequences. After all, every advance in science merely pushes the boundaries of knowledge a little farther, and every question that is answered raises a new question awaiting an answer.

TERMINOLOGY TALKS

(Continued from page 189)

dereal year between two successive perihelion crossings. The length of the anomalistic year is $365^d\ 6^h\ 13^m\ 53^s$.

Eclipse Year

The moon's apparent path among the stars as it encircles the earth does not lie exactly in the ecliptic, the sun's annual starry highway, but is off a little over five degrees at the widest separation. Half of it lies north of the ecliptic; half, south. The crossing points are the nodes. These nodes move westward along the ecliptic, making a complete circuit in 18.6 years. Since eclipses of the sun can occur only when both sun and moon are near the same node, and eclipses of the moon when the two are at opposite nodes, the motion of the nodes must be considered in calculating eclipse seasons. The sun moves (apparently) eastward among the stars; the moon's nodes, westward. It will thus be less than a year for two successive meetings of the sun with the same node. This interval of $346^d\ 14^h\ 52^m\ 51^s$ is known as the eclipse year.

Amateur Astronomers

Who's Who at the Northeast Regional Convention

GATHERINGS of amateur astronomers will take place during the coming months in many parts of the country. It is planned for this year, starting with the April 28-29 convention of the Northeast region of the Astronomical League at Springfield, Mass., to curtail the meeting reports in favor of keys to the group photographs. Thus many amateurs may get to know their fellow hobbyists by sight as well as by correspondence. This should be of special value to those expecting to observe the eclipse and to attend the league general convention at Chapel Hill.

The Springfield convention was held under the auspices of the Springfield Stars Club, with the co-operation of the Springfield Museum of Natural History, whose director, Dr. Lee Otis, gave the address of welcome. Frank Korkosz, builder of the Korkosz projector, gave a demonstration in the Seymour Planetarium at the museum. John E. Welch was convention chairman.

Not shown in the picture were the hosts for Saturday evening at Amherst College, Drs. Warren K. Green and Albert P. Linnell, of the astronomy department. Unfortunately, cloudy skies prevented observing with the Amherst 18-inch refractor, but the observatory's photoelectric equipment was on exhibition, and its use was demonstrated.

G. R. Wright, chairman of the Middle East region and of the Chapel Hill convention, described plans to conduct variable star and meteor observing instruction under the skies of the Morehead Planetarium, and outlined the convention program. Paul W. Stevens, chairman of the Northeast region, discussed the effect of atmospheric refraction on the westernmost point of visibility of the eclipse (see page 196), and urged amateurs to select observing sites in many parts of the path of the annular phase to make sure the eclipse would be observed in spite of locally unfavorable weather.

At the instruments session Sunday morning, G. Camilli, of the Pittsfield Amateur Astronomers, described the Maksutov telescope he has completed. Motion pictures of 20-inch mirror grinding and polishing by members of the host society were shown, but the mirror still has about 40 hours of work to be done on it. Members of the Utica group described a simple "sky transit" for alt-azimuth measurements of features of the northern lights; they also told of their plans to build a 14-inch reflector and house it on a plot of land given them by a friendly farmer.

Chairman Stevens presented the possibility of holding the 1952 regional convention in the Rochester-Buffalo area, with the societies in those cities co-operating as hosts. Officers of the region for 1951-52 are: Paul W. Stevens, re-elected chairman; Clarence Johnson, re-elected vice-chairman; Charles Moulton, secretary; Mrs. Frank Velardi, treasurer.

KEY TO PHOTOGRAPH

1. J. E. Welch, S. *2.* A. O. Protas, NYC. *3.* G. Schadt, S. *4.* J. Rothschild, NYC. *5.* C. W. Bennett, Milford, Conn. *6.* B. Dodd, B. *7.* Mrs. Rothschild, NYC. *8.* H. D. Ricker, B. *9.* R. Reniff, S. *10.* G. Camilli, Dalton, Mass. *11.* A. Wyman, B. *12.* P. Atwood, NH. *13.* H. Oliver, S. *14.* W. Pearson, S. *15.* Mrs. Holmes, NH. *16.* F. Stebbins, S. *17.* R. Rodin, S. *18.* F. Velardi, NH. *19.* E. Johnson, S. *20.* S. Furnald, NH.

21. W. K. Davis, S. *22.* E. Naber, B. *23.* F. Burnham, NH. *24.* Mrs. Velardi, NH. *25.* K. Hendrie, B. *26.* F. Welter, NH. *27.* L. Budd, NH. *28.* F. Pflug, B. *29.* C. Federer, B. *30.* Stone, W. Hartford, Conn.

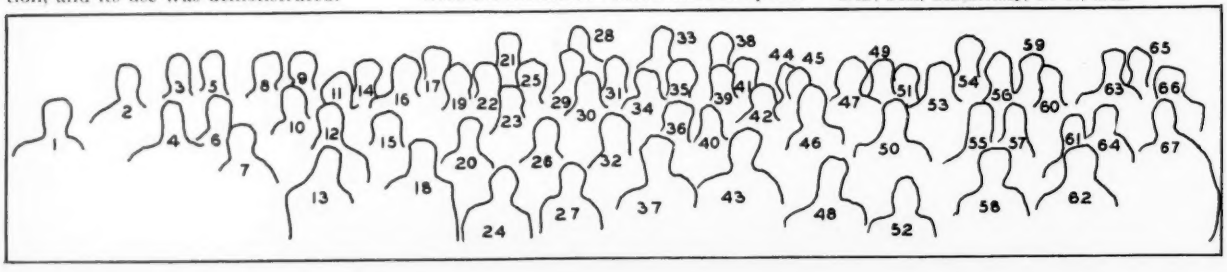
31. N. J. Heines, Paterson, N. J. *32.* D. Hayes, SCH. *33.* H. B. Chase, B. *34.* J. Wallace, SCH. *35.* C. Cook, B. *36.* I. Bootier, SCH. *37.* Mrs. Christman, Utica, N.Y. *38.* Mrs. Chase, B. *39.* C. Moulton, S. *40.* M. Woodrow, SCH.

41. C. B. Ford, Suffield, Conn. *42.* Mrs. H. Sigsworth, SCH. *43.* H. Christman, Utica, N.Y. *44.* Mrs. Ford, Suffield, Conn. *45.* C. Johnson, SCH. *46.* M. Jackson, SCH. *47.* P. Stevens, Rochester, N. Y. *48.* T. Federer, B. *49.* R. Thomson, SCH. *50.* W. R. Ransom, B.

51. D. Kimball, NH. *52.* B. Federer, B. *53.* R. LaPelle, S. *54.* E. Oravec, NYC. *55.* W. Fillmore, S. *56.* C. Cuevas, NYC. *57.* Mrs. E. Rademacher, NH. *58.* Mrs. Federer, B. *59.* S. Gardiner, B. *60.* J. Patterson, B.

61. Mrs. Gardiner, B. *62.* R. Wright, Worcester, Mass. *63.* K. Weitzenhoffer, NYC. *64.* Mrs. A. Downing, B. *65.* O. Hanson, Jamestown, N. Y. *66.* B. Hanson, Jamestown, N.Y. *67.* J. W. Gagan, B.

B, Boston, Mass., area; NH, New Haven, Conn., area; NYC, New York City; S, Springfield, Mass., area; SCH, Schenectady, N. Y., area.



The Springfield, Mass., convention of the Northeast region of the Astronomical League, April 28-29, 1951.

MID-STATES CONVENTION

The Central Missouri Amateur Astronomers will be host society to the second Mid-States amateur astronomers convention, to be held at the Morrison Observatory, Central College, Fayette, Mo., the weekend of June 15-17. Registration will begin at noon on Friday, and that evening Dr. Frank Edmonds, of the University of Missouri, will give a lecture, preceded by astronomical movies. Later, there will be an organized observing session on AAVSO methods and ALPO drawing techniques, use being made of the three telescopes at the observatory.

After a session for 10-minute papers Saturday morning, solar observing will be demonstrated. The afternoon will have another session for papers and examination of exhibits. At 4:15 p.m., delegates will discuss plans to form the area into a new region of the Astronomical League. The banquet that evening will feature a talk by Dr. C. C. Wylie, University of Iowa, on "Recording Meteor Observations." Another observing session is also scheduled.

On Sunday morning, the site of the 1952 convention will be selected, and plans made to form a motor convoy for the trip to Chapel Hill to attend the Astronomical League convention and view the eclipse of September 1st. Sunday afternoon, delegates will travel to Columbia, Mo., to inspect the newly renovated Laws Observatory of the University of Missouri.

All amateur and professional astronomers are invited to attend the Mid-States convention. Dormitory accommodations are available, the cost of housing and meals, including the banquet, to be about six dollars a person. Inquiries should be addressed to Dr. Floyd F. Helton, Morrison Observatory, Fayette, Mo., or to Russell C. Maag, 611 Bluff St., Fulton, Mo., who is secretary of the Central Missouri Amateur Astronomers.

NORTHWEST REGIONAL MEETING AT VICTORIA

The Northwest region of the Astronomical League will hold its 1951 convention at Victoria, B. C., Canada, Friday and Saturday, July 20th and 21st. The Victoria Centre of the Royal Astronomical Society of Canada is co-operating in the plans. Through the courtesy of Dr. J. A. Pearce, delegates have been promised the use of the 72-inch reflector of the Dominion Astrophysical Observatory on Friday evening, July 20th. A member of the observatory staff will appear on the program the following day, when business sessions and other activities of the region will be held, with C. A. Wood, chairman of the Northwest region, presiding.

PORTLAND ASTRONOMICAL SOCIETY

A memorial resolution to the late Mrs. Frank A. Bartlett has been passed by the Portland Astronomical Society at its meeting of April 2nd. As one of the founding members, Mrs. Bartlett is credited with initiating the move to organize the society and acting as secretary for several years. The resolution points out that this Oregon society itself is a monument to her astronomical efforts.

THIS MONTH'S MEETINGS

Cambridge, Mass.: The Bond Astronomical Club will hold its annual picnic at Harvard Observatory in Cambridge on Saturday, June 9th, at 3:00 p.m. Solar prominences will be observed with Richard Dunn's monochromator and the 15-inch refractor.

Columbus, Ohio: "Mountains on the Moon" will be discussed by Philip Stanger at the June 8th meeting of the Columbus Astronomical Society, at 8:00 p.m. at McMillin Observatory.

Dallas, Tex.: On June 25th the Texas Astronomical Society will hold a field meet at Dr. McNeill's "Log House," 7814 Forney Rd., at 8:00 p.m. Visitors are welcome.

Detroit, Mich.: The Detroit Astronomical Society will meet at the Cranbrook Institute of Science, Bloomfield Hills, on June 10th at 3 o'clock, when W. C. Nicholson will speak on "Some Geological Trends of the Solar System." A picnic supper and a night of observing will follow.

Geneva, Ill.: The annual picnic of the Fox Valley Astronomical Society will be held at Aurora College on June 10th. Carl H. Gamble, of Moline, will speak at 5:00. A picnic supper on the college campus at 6:30 p.m. will be followed by observing.

Indianapolis, Ind.: Meeting at Goethe Link Observatory, in Brooklyn, Ind., on June 3rd, the Indiana Astronomical Society will hear Dr. Link discuss "Research at Link Observatory." There will be outdoor observations.

Sacramento, Calif.: On June 5th at 8:00 p.m., Leon E. Salanave, of Sacramento Junior College, will speak on "What Is Being Done at Palomar." This is a public meeting of the Sacramento Valley Astronomical Society, to be held at the Little Theater, Sacramento Junior College.

Washington, D. C.: Frederick H. Hollander, of the Nautical Almanac Office, will speak on "Application of IBM Machines at the U. S. Naval Observatory," at the June 2nd meeting of the National Capital Astronomers, 8:15 p.m. in the Commerce Building auditorium.

NEW LEAGUE MEMBER

The Atlanta Astronomy Club, with headquarters at the Bradley Observatory of Agnes Scott College, in Decatur, Ga., has joined the Astronomical League. Secretary-treasurer of the society is J. Conrad Meaders, 1474 Everhart St., S. W., Atlanta, Ga.

Planetarium Notes

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.
SCHEDULE: 4 p.m. Monday, Wednesday, and Friday; Thursday evening, 7:45, 8:30, 9:30 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BOSTON: *Little Planetarium.* Boston Museum of Science, Science Park, Boston 14, Mass. Richmond 2-1410.
SCHEDULE: Tuesday thru Friday at 3:30 p.m.; Saturday, 11 a.m., 2, 3, and 4 p.m.; Sunday, 2, 3, and 4 p.m. Spitz projector. In charge, Charles A. Federer, Jr.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.
SCHEDULE: Sundays, 2:00 to 5:30 p.m. Admission free. Spitz projector. For special lectures address Elsworth Jaeger, director of education.

CHAPEL HILL: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N.C.
SCHEDULE: Daily at 8:30 p.m.; Saturday and Sunday at 3:00 p.m. Zeiss projector. Manager, A. F. Jenzano.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 1428.
SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Sundays, 2:30 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 1, Mo., Chestnut 2215.
SCHEDULE: Wednesday and Saturday, 3:30 p.m.; Sunday, 3:00 and 5:00 p.m. Spitz projector. Director, Charles G. Wilder.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 9787, Los Feliz Station, Los Angeles 27, Calif., Olympia 1191.
SCHEDULE: Wednesday and Thursday at 8:30 p.m.; Friday, Saturday, and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

NEW YORK CITY: *Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Endicott 2-8500.
SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 2, 3, 4, 5, and 8:30 p.m.; Wednesdays and Fridays, 11 a.m., for school groups. Zeiss projector. Chairman, Robert R. Coles.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.
SCHEDULE: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 4300.
SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 3:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.
SCHEDULE: Saturday, Sunday, and Wednesday, 4:00 p.m.; Tuesday, Thursday, and Friday, 8:00 p.m.; Saturday show for children only, 10:30 a.m. Spitz projector. Director, Stanley H. Shirk.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.
SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, Frank D. Korkosz.

STAMFORD: *Stamford Museum Planetarium.* Courtland Park, Stamford, Conn.
SCHEDULE: Sunday, 4:15 p.m. Special showings on request. Admission free. Spitz projector. Director, Robert E. Cox.

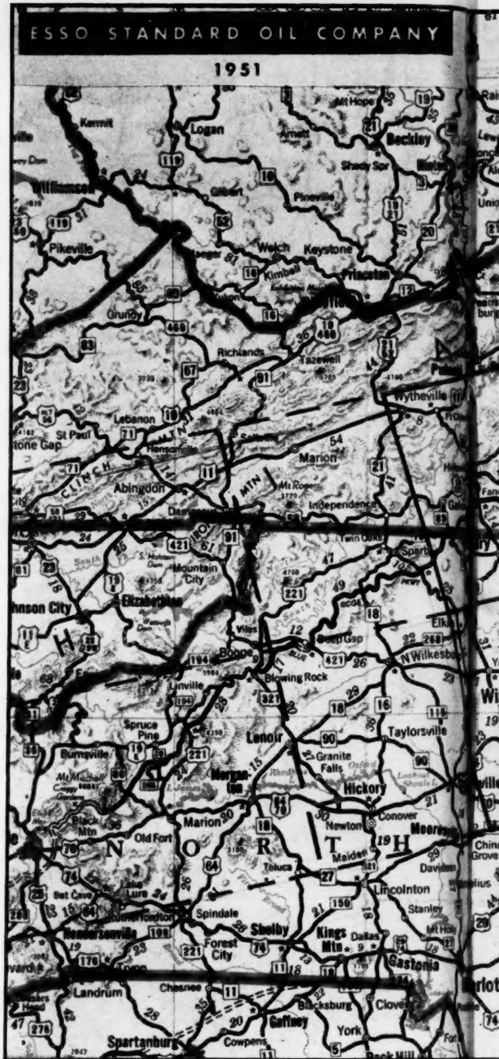
Eclipse Observing Information

UNITED STATES Naval Observatory *Circular* No. 27, prepared under the supervision of Isabel M. Lewis, is chiefly for the use of those who plan to make scientific observations of the eclipse of September 1st, within that part of the path of the annular phase which lies in the United States. According to the circular, the path has an extent of about 280 miles on land and a width of about 95 miles. The combined effect of refraction and elevation (greater than 400 feet) upon the times of beginning and ending of the annular phase has been taken into account for 20 towns in the region, and the following list is an abstract that should be of value to the amateur observer:

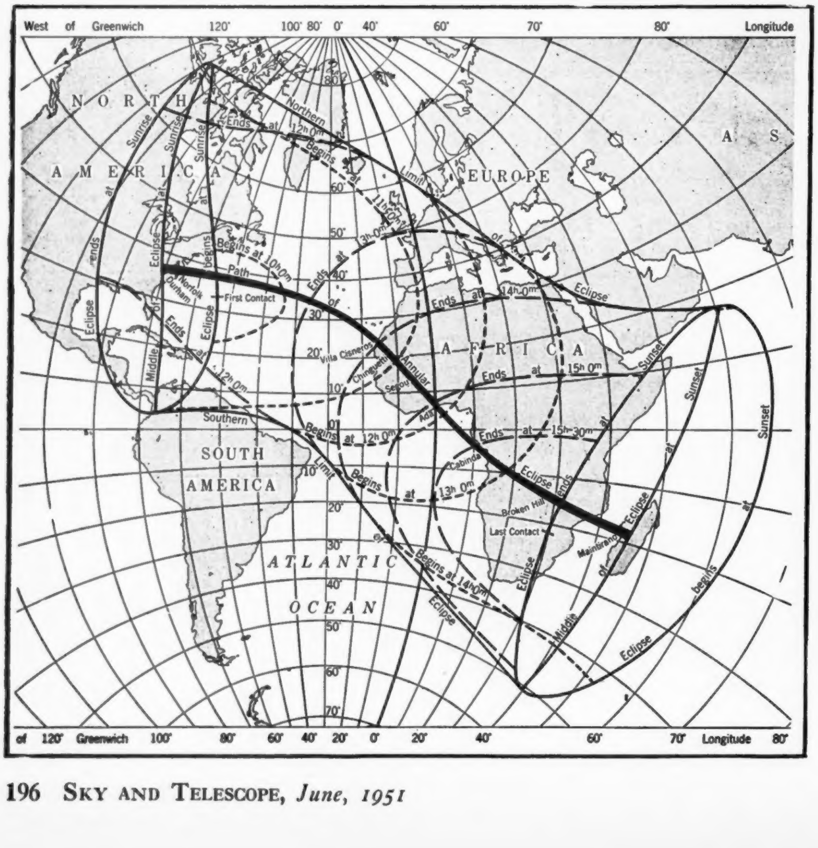
Place and Elevation		*Second Contact*	*Annular Duration Min. Sec.*
Winston-Salem, N.C.	(860)	5:57:21	2 21
Hillsville, Va.	(2,570)	5:57:41	2 16
Greensboro, N.C.	(840)	5:57:26	2 08
Martinsville, Va.	(1,025)	5:57:32	2 30
Danville, Va.	(410)	5:57:23	2 40
Roxboro, N. C.	(650)	5:57:21	2 32
Durham, N.C.	(405)	5:57:48	1 18
Henderson, N.C.	(505)	5:57:28	2 14
Lawrenceville, Va.		5:57:28	2 40
Emporia, Va.		5:57:27	2 38
Petersburg, Va.		5:57:54	2 12
Suffolk, Va.		5:57:33	2 29
Williamsburg, Va.		5:57:54	2 18
Yorktown, Va.		5:57:50	2 25
Hampton, Va.		5:57:38	2 39
Newport News, Va.		5:57:36	2 40
Norfolk, Va.		5:57:34	2 38
Portsmouth, Va.		5:57:34	2 35
Virginia Beach, Va.		5:57:37	2 36
Cape Charles, Va. (Ry.)		5:57:55	2 23

The time of second contact (beginning of annular eclipse) is a.m. Eastern standard. The duration is in minutes and seconds. For example, at Newport News, the annular phase begins at 5:57:36 a.m. EST, and lasts two minutes 40 seconds, until 6:00:16. (The end of the partial phase occurs more than an hour later, at 7:07:05.) The circular also lists the position angles of the contacts. Sunrise at the coast occurs about 25 minutes before the annular phase begins, and at mid-eclipse the sun will have an altitude of about four degrees. The circular states that the most favorable location for observing the eclipse should be in the general vicinity of Norfolk, Va.

Although the solid line running across the shadow path near Elkin, N.C., corresponds to geometrical sunrise, actual sunrise occurs along that line about four minutes before the middle of the annular phase. This is caused by refraction lifting the apparent sun by more than half a degree. The accompanying diagram by Paul W. Stevens shows the effect of refraction and also of the dip of the horizon for an observer at two considerable elevations. These are approximate values because the precise curvature of the sun's rays in the atmosphere is not known. Furthermore, the observer is assumed to be on a height of land overlooking the sea, whereas the actual height of the visible horizon for inland stations reduces the amount of the advance in the time of sunrise.

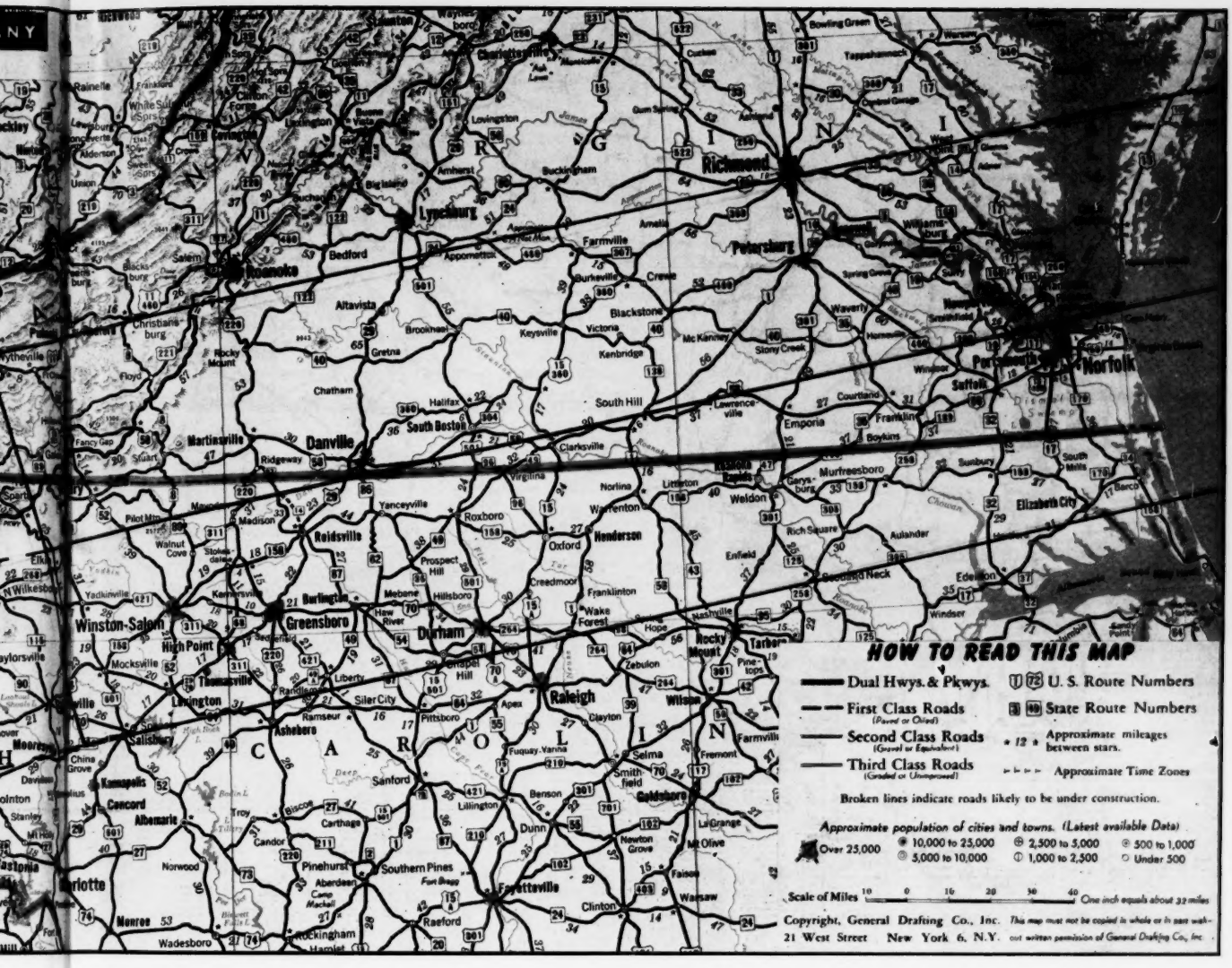


The central line and annular limits are here plotte



On the map, the dashed line across the path just to the west of Deep Gap shows the actual locations from which an observer at sea level should see the sun rising in the middle of the annular phase. This is the same line as that marked "R" in the sketch map on page 162 of the May issue. From both Grandfather Mountain (5,964 feet) and Mt. Mitchell (6,684 feet), the eclipse should not become annular until a few minutes after sunrise, and even Clingman's Dome (6,642 feet) in the Smokies may be high enough to show the annular phase after sunrise, depending on the character of

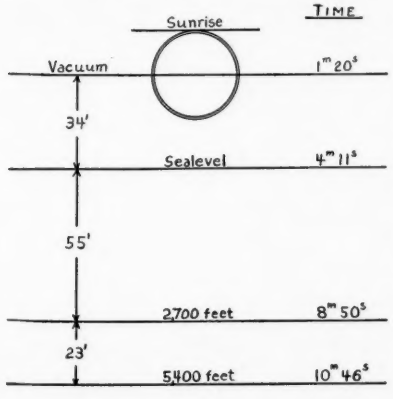
The annular phase of the eclipse of September 1st begins at sunrise in North Carolina and Virginia and extends across Africa to Madagascar at sunset. The eclipse will be seen partial over a part of eastern North America, part of Europe, and all of Africa. This chart is adapted from the "American Ephemeris and Nautical Almanac." Universal time is used.



are here plotted on the Esso Southeast United States road map, reproduced by permission of the copyright owner, General Drafting Co., Inc.

the horizon to the east of that location.

On the coast, the apparent emerging of the solar crescent out of the sea will be a novel phenomenon. For vacationers, hotel rooms overlooking the ocean at fashionable Virginia Beach will be in order.



Sunrise delays, in minutes of arc and in time taking into account refraction and the observer's altitude. Chart by Paul W. Stevens.

Mr. Stevens notes that it would be worthwhile for some observers to choose stations as near the northern or southern limits as possible. Such an observer, as at Chapel Hill, will not see a symmetrical ring of sunlight around the moon at any time, but the darkening of the landscape will be nearly as much as on the central line. The novelty lies in the antics of the cusps of the solar crescent. One will move at a decreasing rate that will become steady as the time of mid-eclipse approaches. The other will move in an erratic fashion that includes a reversal of direction and a rapid swing nearly halfway around the limb of the sun. It should make a very interesting motion picture. Finally, Baily's beads will be observable for a maximum length of time near the edges of the annular path.

WEST COAST CONVENTION

The Astronomical Society of San Diego and the Amateur Telescope Makers and Astronomical Club will jointly sponsor the third annual convention of western amateur astronomers this summer, to be held August 13-15 in San Diego's Balboa Park. A trip to Palomar Observatory is planned.

Interested persons may obtain further information from the chairman of the convention committee, Carl W. Dickson, 6951 Mt. Vernon St., Lemon Grove, Calif.

CORRECTION

In the article on "The Source of Energy in the Fainter Stars," in the April, 1951, issue of **Sky and Telescope**, there occurred an editorial error. The star in the illustration and caption on page 138 should have been designated o_2 Eridani C and not σ_2 Eridani C. On page 139, third column, line 7, the same correction should be made.—ED.

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BOOKS AND THE SKY

THE NININGER COLLECTION OF METEORITES

H. H. Nininger and **Addie D. Nininger.** American Meteorite Museum, Winslow, Ariz., 1950. 144 pages plus 38 plates. $3.00.

ON November 9, 1923, at 8:57 p.m., a brilliant fireball fell across northern Oklahoma and southern Kansas. The scientific collection and study of meteorites owes much to the chance witnessing of this spectacular phenomenon by Dr. H. H. Nininger. Incited by this fall he undertook an extensive search of the area in which the fireball might have dropped meteorites onto the ground. In his search for these meteorites, he discovered, within the same area, two other meteorites that definitely did not come from the fireball of November, 1923. From the results of this search, Dr. Nininger concluded that meteorites must be much more abundant on the earth's surface than previously supposed, and in this way an idea was born that served as an impetus to him for making a systematic search for meteorites. For more than 27 years, Dr. and Mrs. Nininger have pursued, with ceaseless effort and enthusiasm, an intensive program of education, searching, and collection, with the result that today they have amassed the splendid meteorite collection that is the subject of their present book.

The book contains a catalogue, together with maps and field notes, of the Nininger collection. However, the book is more than a catalogue, for the 10-page introduction and the field notes give a brief historical account of the unique way in which this collection was gathered. In addition, there is an extensive series of excellent photographs of meteorites in the collection.

I have found only the following printing errors in the book; however, if there are errors in the catalogue itself they will be revealed only by extended use. In the discussion of the Xiquipilco, Mexico, meteorite on page 14, reference is made to Pl. III, Fig. 8, but it should evidently be to Pl. III, Fig. 3. The map of New Mexico on page 25 is turned through 90°, evidently by oversight.

For the use of active workers in the field, the catalogue would be more convenient if it included the very important datum, the percentage of nickel in the free metal, whenever it was available; and if the 51 recently acquired meteorites catalogued in the separate supplement had been intercalated into the main catalogue. I would have been interested in a separate tabulation of the finds and falls in the summary at the top of page 121. Finally, I believe that Hey's appendix to Prior's catalogue deserves separate mention among the great meteorite catalogues mentioned on page 9.

The Nininger collection, which I had the pleasure of examining recently, is representative of the large variety of meteorites that are known, and is certainly one of the world's most valuable collections. Its scientific value is greatly enhanced by the large number of cut, polished, and etched surfaces that have been prepared. This collection is unique in that it is largely the result of the field program carried out by the Niningers themselves, while all other large collections have been built up mostly by the purchase and exchange of specimens.

In the history of meteorite collecting, no one has equaled or even approached, in the total number of finds, the 27-year program of the Niningers. As one example of their enormous contribution, they alone have been responsible for about 85 per cent of all the meteorites discovered in Kansas since 1923. And their efforts have also yielded many meteorites in Colorado, Nebraska, Wyoming, New Mexico, Texas, and other areas.

The extensive educational program of the Niningers has stimulated much interest in meteorites, especially in the Middle West and Southwest, and thus, I believe, the dividends of their program have been paid to science far in excess of the immediate return of meteorites.

CARL AUGUST BAUER
Harvard College Observatory

ATOMIC ENERGY AND THE HYDROGEN BOMB

Gerald Wendt. Medill McBride Company, New York, 1950. 192 pages. $2.75.

HYDROGEN BOMBS are more easily said than done. And the simple comparison with the proton-proton reaction that may be the method of energy generation in the sun and other stars does not take into account the time factor. In the bomb, reactions involving small fractions of a second call for such rare elements as heavy hydrogen (nucleus of a proton and a neutron) and heavier hydrogen (nucleus of a proton and two neutrons). These are known today as deuterium and tritium, and under proper circumstances they can react with each other to form helium, ejecting a neutron and releasing a considerable amount of energy. The average time required for the deuterium-tritium reaction is about 1/100,000 second at a temperature of about 40 million degrees.

The high-temperature requirement of a hydrogen bomb makes it fairly certain that an ordinary atomic or uranium bomb would be needed to "trigger" the explosion, but how high a temperature is reached in the uranium bomb and how long it is maintained is either unknown or is a secret known only to the Atomic Energy Commission. Dr. Wendt's book, however, contains no secrets; all of his facts are based on published information.

Even were a hydrogen bomb impossible to produce, the prospect of a war with uranium bombs is terrifying and its aftermath awful. As Dr. Wendt points out, "The highest purpose we can have in developing [the hydrogen bomb] is to make sure that no enemy will use it and that, in that case, we will not use it. If that is so, the hydrogen bomb is a psychological weapon and should be so recognized and used as such."

But the atomic era may produce other

weapons even more devastating to life than bombs can be. The monthly radioactively poisonous products of the atomic reactors at the Hanford Works in Washington State are as potent as 250 million grams of radium would be. "Now the Hanford Works produce, as waste, the equivalent of nearly 10 million grams or ten tons of radium per day." The disposal problem is very serious; at present the wastes are stored in huge metal cans and buried in concrete-lined pits.

This same radioactive waste of a month, however, could be used in warfare to contaminate about 150 square miles of land so thoroughly that it would be uninhabitable. The control of such a lethal weapon would be so uncertain as to make it suicidal to use. The book quotes Harrison Brown, of the University of Chicago, as saying, "We are faced with the ironical conclusion that it becomes easier to kill all people in the world than just a part of them." Which leads Dr. Wendt to comment, "If previous wars have been tragic folly the next one would be fatal madness."

Nevertheless, in the later portions of this book, describing some of the peaceful uses of atomic energy, which ought to be called nuclear energy, it is suggested that in the long run even the tragedy of such a war might be offset by the advance of civilization that may come from our control over the atom. Already, radioactive isotopes have served to make new discoveries in medicine, biology, and engineering. The atomic power plant cannot be far in the future. But if uranium and thorium ores are the only sources of such energy, a few hundred years may see even the atomic age drawing to a close, to be superseded, Dr. Wendt suggests, when we capture solar energy.

Our nearest star, of course, is described in this book as a self-sufficient source of nuclear energy. It is unfortunate that Dr. Wendt, onetime lecturer at New York's Hayden Planetarium, reveals in this chapter more than in any other the apparent haste with which the book was compiled. The carbon cycle is not "now almost universally accepted as representing the truth" of the sun's energy generation. The reversing layer of the sun's atmosphere is not mentioned, or is what is described by Dr. Wendt as the photosphere, and the corona is described as a very thin atmosphere of electrons that does not show the spectra of the chemical elements. The discovery of the "hot" corona by Edlén was based, of course, upon the analysis of its spectrum as being produced by highly ionized elements.

In addition to some inconsistencies on the author's part, the book is seriously marred, and the reader annoyed, by at least two dozen misprints of the most obvious sort. The type is large, and the book is well printed, so these careless errors are all the more noticeable. The author informs us that these are to be eliminated in the second printing now in progress.

"The one purpose of this book is to evaluate the possibilities so that young men and women can plan for life in the atomic age ahead." Within the space he has used, Dr. Wendt has probably done much to fulfill this purpose, and his book is equally suitable for persons of all ages and walks of life, with no scientific or technical knowledge required. Kirtley F. Mather has called it "the most informative [non-technical] book upon its subject that is currently available."

C. A. F.

NEW BOOKS RECEIVED

INTRODUCING THE UNIVERSE, *James C. Hickey*, 1951, *Dodd, Mead*. 154 pages. $3.50.

The author, an amateur astronomer and newspaper man, wrote the "Stars of the Week" column in the late New York *Sun* for 15 years starting in 1934. Here, for the beginner in astronomy, he tours the universe from the earth to outermost space.

PHOTOMETRIC ATLAS OF THE NEAR INFRA-RED SOLAR SPECTRUM, λ 8465 TO λ 25,242, *Mohler, Pierce, McMath, and Goldberg*, 1950, *University of Michigan Press*. Unpaged. $4.00.

This atlas is compiled from infrared solar spectrograms made with the Snow telescope at Mount Wilson Observatory, under a cooperative arrangement with McMath-Hulbert Observatory, whereby the observing personnel and the infrared instrumentation were furnished by the latter. The reproductions are of original tracings, reduced about 5/8. There are 234 tracings, two on a page measuring 19 by 12¼ inches. There is an overlap of about 300 angstroms with the Utrecht *Atlas* at the short wave-length end.

The authors state, "A companion volume, now being prepared for publication, will contain wave-lengths, equivalent widths, and identifications insofar as they are known, for all solar and telluric lines in the atlas between 1.4 μ and 2.5 μ."

A HANDBOOK OF SPACE FLIGHT, *Proell* and *Bowman*, 1950, *Perastadion Press*, 10630 S. St. Louis Ave., Chicago. 185 pages. $3.50.

The authors state that it is the object of this book "to provide in an accessible and collected form, a sequence of tables and tabulated information . . . especially useful for the investigator in the field" of rocketry and space flight. Their final objective is to show "how little is known about important data and . . . above all to stimulate the necessary research needed to gather such data."

The book includes 94 tables grouped under properties of materials, physical, astronomical, and rocket data, miscellaneous. Sources and dates of the material are not given.

THE GROWTH OF PHYSICAL SCIENCE, *Sir James Jeans*, 1951, *Cambridge University Press*. 364 pages. $3.75.

The second edition of a book posthumously published in 1947, in which the famous English astronomer reviews for the lay reader the progress of science from ancient beginnings to the present era.

THE NEW PHYSICS, *Sir C. V. Raman*, 1951, *Philosophical Library*. 144 pages. $3.75.

A description of the meaning of modern physics, based on a series of radio talks originally given in India by one of the world's most renowned physicists.

CONSTANTES FONDAMENTALES DE L'ASTRONOMIE, 1950, *Centre National de la Recherche Scientifique*, 45, Rue d'Ulm, Paris 6e. 130 pages. 900 fr.

Published as the 25th report of international colloquia of the French National Center of Scientific Research, this book contains papers given and reports of the meeting on the fundamental constants of astronomy held in Paris in March-April, 1950 (*Sky and Telescope*, July, 1950, page 215). More than half of the material is in English, the rest in French. The address by Sir Harold Spencer Jones on "The System of Astronomical Constants" is included, as well as the texts of the nine principal reports by delegates.

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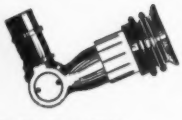

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GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

How to Build a Quartz Monochromator — III

By Richard B. Dunn, *Harvard Observatory*

THE OPERATION of this type of filter depends almost entirely on the optical properties of certain crystals. Our discussion must be very brief and simplified; the reader is referred to elementary books on physics and optics for detailed coverage of the optical principles involved.

We shall assume that most amateur telescope makers are familiar with the operation of polaroid, whereby ordinary light is rendered plane-polarized by passing through one sheet of polaroid. Let a second piece of polaroid be placed after the first and rotated. Light passing through both polaroids appears to be alternately extinguished and transmitted, depending on whether the polaroids are crossed or parallel to each other. Between the crossed and uncrossed positions there is any degree of transmission according to the angle between the polaroids. Polaroid actually consists of a vast quantity of microscopic crystals, such as herapathite, oriented on a suitable translucent base.

In the monochromatic filter, to the quartz crystal following it each polaroid therefore passes light that is plane-polarized in one direction. If the light consists of many wave lengths, the polaroid acts as a selector for those frequencies for which the vibrations are principally in the direction of the transmission axis of the polaroid.

Crystal quartz is an example of a doubly refracting substance. Light incident on the quartz emerges (except under certain circumstances) broken up into two rays: one, the ordinary ray, obeys the law of refraction; the other, the extraordinary ray, obeys this law only along the optical axis.

If we examine light passing perpendicular to a plate cut with its surfaces parallel to the optical axis, the emergent beam is elliptically polarized. This arises from the fact that the ordinary and extraordinary rays travel at different velocities through the crystal. In fact, the velocity of the extraordinary ray varies with direction in the crystal; therefore, its index of refraction also depends on the direction of propagation. Along the optical axis the velocity is practically the same as that of the ordinary ray, and the index of the extraordinary is nearly the same as that of the ordinary ray. But in the direction at right angles to the optical axis (mentioned above), the difference in the velocities is greatest, the indices have their maximum difference (0.009 in quartz), and the maximum birefringent effect is obtained. This is the direction in which the light passes in our monochromator crystal elements.

In Fig. 1a, the formation of two wave fronts from an instantaneous point source inside the crystal is shown. The one for the ordinary ray is spherical; the other for the extraordinary ray is ellipsoidal. In Fig. 1b, which corresponds to a monochromator element, the fronts travel through the crystal at the maximum possible difference in speed. Fig. 1c shows that along the optical axis both waves travel at the same speed, while Fig. 1d illustrates the general case, showing how a single beam is split into two beams by double refraction.

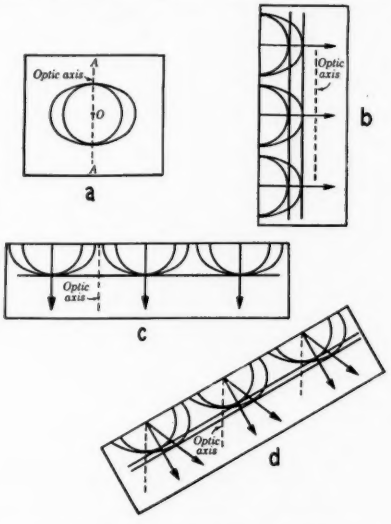


Fig. 1. The phenomenon of double refraction. In each case the optical axis is vertical. Reproduced from "College Physics," Sears and Zemansky, 1948, Addison-Wesley, Cambridge, Mass.

However, if the rays in Fig. 1b are from the same monochromatic light source, because of their differing velocities they should be alternately in and out of phase with each other as they travel through the crystal. The phase difference upon emergence depends on the thickness of the section of crystal (path length), the birefringence of the crystal, and the wave length of the light (λ). There is a fundamental thickness, d_0, for the completion of this "in phase" and "out of phase" cycle, determined from the formula:

$$d_0 = \lambda/(n_e - n_o),$$

where n_e is the extraordinary index, n_o the ordinary index. Since this fundamental thickness depends directly on the wave length, it will be different for different wave lengths. This relationship makes the filter possible.

As monochromatic light passes through the fundamental thickness, it undergoes changes that can be represented by a se-

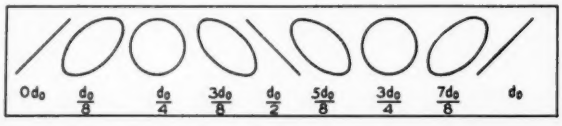


Fig. 2. Polarization figures in passing through a fundamental thickness.

ries of Lissajous figures. In Fig. 2, the light is first plane-polarized, then elliptically polarized, circularly polarized, and so forth, depending on the fraction of the fundamental thickness through which it has advanced. After one d_0 thickness, the light is plane-polarized and parallel to the incident polarized light. But sunlight is of all wave lengths, and since the fundamental thickness is different for different wave lengths, some wave lengths will emerge from a particular crystal elliptically polarized, others circularly polarized, and still others plane-polarized, perhaps at right angles to the original orientation.

When this light strikes the second polaroid, different waves will be transmitted in different intensities, because of the differences in their states of polarization. It is evident that no one crystal-polaroid combination can cut off completely more than a few specific wave lengths. Depending on the crystal thickness, a narrow or broad band will be nearly fully transmitted (neglecting absorption losses), adjacent to an equally narrow or broad band that will be nearly completely eliminated. The crystal has effectively introduced the well-known phenomenon of interference.

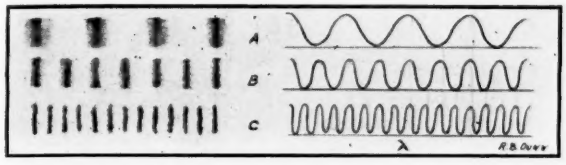


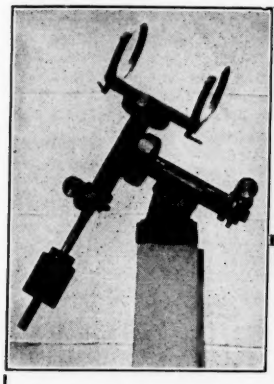
Fig. 3. Spectrum and intensity curves for various crystal thicknesses. C is the thickest case.

Suppose white light is allowed to pass through a polaroid and through an element of our filter. At this point, nothing is seen to happen, but when another polaroid is placed parallel or perpendicular to the first, some colors are excluded and some are transmitted. If the emergent light is analyzed with a spectroscope, the continuous spectrum is seen broken up into a series of broad alternate dark and bright bands. Their spacing and number depends, as already explained, on the wave lengths and the thickness of the quartz. Those that have gone through the cycle from plane back to the same plane will be transmitted fully (parallel polaroids), but those that have gone through just half the cycle will be absorbed by the second polaroid.

If the plate is thin, a few broad bands are formed in the spectroscope as in A, Fig. 3. As the plates get thicker the number of maxima and minima increases, as in B and C. If the polaroids were crossed instead of parallel, there would be a phase reversal; the dark bands would become bright, and the bright ones would be dark.

Now, if a number of crystals whose thicknesses are in the ratios 1, 2, 4, 8, 16, . . . $2^{(n-1)}$, are placed between parallel or crossed polaroids, narrow transmission bands separated by wide dark bands result. Fig. 4 shows the effect as seen in the spectroscope. In the top portion of the diagram the individual crystal pattern is given for each thickness; note that the dark areas indicate minimum transmission. In the lower portion the combined transmission is shown as each crystal is added to the preceding plate; here the dark lines indicate transmission, the last one being that of the desired wave length for final observation.

Of course, in the finished filter there are a few more transmitted frequencies, but these are widely spaced along the spectrum and can be eliminated by putting in glass filters or multilayer interference filters. The latter consist of a series of evaporated layers of materials of the cor-



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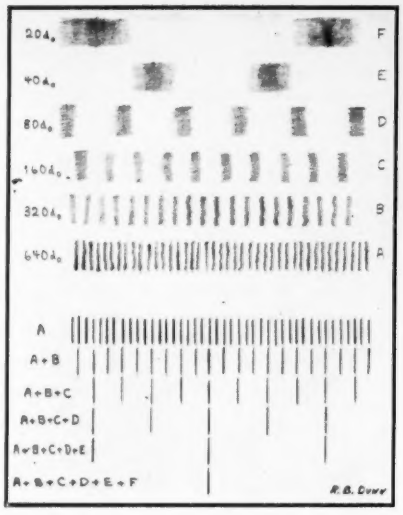

Fig. 4. The absorption of various portions of the spectrum by crystal elements of various multiples of the fundamental thickness. The thickest element (A) gives closely spaced maxima and minima of transmission and determines the exact position of the final passband. The lower portion of the illustration shows the transmission (dark lines) of the combined crystals, beginning with A.

rect indices of refraction. The passband can be made to a half width of only 25-50 angstroms, and the transmission may be as high as 70 per cent. At present, these filters are rather expensive, but are mentioned here as someone might want to build a monochromator for other than the H-alpha line.

Emerging from each crystal the ordinary and extraordinary rays are vibrating at right angles to each other. Consequently, as shown in the diagram in April, the polaroid should be oriented at 45° to the optical axis of the crystals so as not to eliminate either the ordinary or extraordinary ray and to prevent a phase change and unwanted interference phenomena.

In earlier practice, it was thought necessary to correct for a change in focus of the ordinary and extraordinary rays by rotating the thickest crystal through 90°, so that the ordinary ray in the first crystals would be the extraordinary ray in the last, and both would go through about the same crystal thickness. The diagram on page 149 in April shows this arrangement, but the correction of the last crystal is now considered unnecessary; in fact, theoretically no gain will be had.

A real gain could be had if a split-field polarizer could be used. This consists of calcite and glass wedges arranged so the ordinary and extraordinary beams are separated from each other, one going straight through and the other being diaphragmed out at the side. This type of polarizer, successfully used by Lyot, is extremely expensive, and for most purposes the polaroid sheets work well in the visible spectrum.

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

VISUAL OBSERVING PROGRAMS FOR AMATEURS — XV

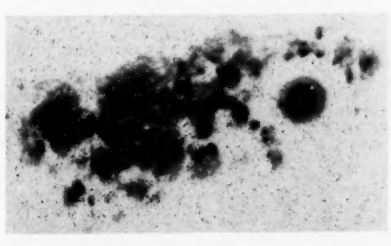
Observing the Sun — (continued)

Counting Sunspots. The first problem is to point the telescope at the sun. To do this, watch the shadow of your telescope tube on the ground, and move the tube until the shadow is the minimum size and round. Then place your hand behind the finder, and bring the round, bright sun's image which shows up on your hand to a central position in the round shadow cast by the finder. Then move your hand back of the solar eyepiece so that the rays emerging behind the telescope from the window or ventilation holes of the Herschel wedge make a bright area on your hand. Move the telescope until this bright area is most intense on your hand. Then look in the solar eyepiece and the sun will surely be in view. In practice some of these steps can usually be omitted, and a finder is not really necessary on a telescope used only for solar work.

In the eyepiece the sun appears to be out of focus. Usually it is best to focus first on the limb, which should be brought to as sharp a line as seeing, which is apt to be unsteady, will permit. Then it will usually be possible to see a sunspot or two and they can be used to obtain a sharper focus. If, as sometimes happens, there are no sunspots, then try to focus for sharp visibility on the granulations or "lemon peel" finish of the sun, but this is not easy to do.

As you look at the sun you find it a gorgeous golden yellow, with brighter areas, like clouds seen from above, near its edge or limb; these are faculae. We may not at first notice the granulations, but on a typical day we do see sunspots. Some are tiny single spots, some are large round ones surrounded by a gray outer circle and are accompanied by a tiny spot or two, while others are groups of a dozen moderate-sized spots. There may be one large, rather complicated group in which the leading (westernmost) spot exhibits considerable detail. Its center, the umbra, is black (umbra means shadow); surrounding it is an irregular gray area, the penumbra, and a few tiny spots may be seen on the edges of the penumbra. These are pores, but pores can exist almost anywhere within a group, or around a group, or by themselves in small groups, or even as single isolated pores. Do not include pores in sunspot counts.

In a large group there are many individual sunspots. Besides the leading, complicated spot, two or three others are penumbral spots, that is, penumbra surrounds the umbra, but most of the spots are merely black dots of various sizes, apparently consisting only of umbrae. There are a few patches of gray haze to be seen, mostly elongated like streamers, which seem to be patches of disconnected penumbra, but some may be underlying umbrae covered over by a veiling. In any case, they are called "wisps."



U. S. Naval Observatory photograph.

Near the middle of the sun, widely separated from any other group, we may see a small vague gray blur, which we might consider a piece of isolated penumbra, but which is referred to as a "veiled group" or faint marking. Of the 60 of these which I have seen during the last year, 15 developed in a day or two into ordinary small groups, some of which later grew to large size, while four represented the final remnants of dying groups.

You may wonder why I have spent all this time describing the appearance of the sun. When do we start counting the sunspots? The reason is that we must first understand what we are seeing. Even yet, we are not ready to do any counting for several reasons. First, we must form some preconceived ideas as to what a group is. These will later be modified by our experience during our apprenticeship.

To decide what constitutes a sunspot group is important but difficult. An isolated spot is called a single spot group. Such groups give us no trouble. An isolated family of 27 spots is also a group, and we are not puzzled by it. But suppose, as often happens, a group expands. Is the new congeries of spots alongside it a new group, or an enlargement of the old? I cannot tell you, nor can anyone else by visual methods; you must make your own decision, and thereafter stick to it for reliability's sake. Is an elongated group which may be coming into view over the eastern limb all one group, or are the concentrations of spots which you see at each end of it so far separated that you should consider it two groups?

Suppose pores suddenly appear between two existing groups, filling in the gap, so that eventually it all becomes one large group. At what point does the ensemble cease to be two groups and become one larger group? Suppose a group disintegrates and the spots which formerly lay between its preceding and following complexes disappear. Does the group then become two groups and at what point does it do so? Suppose that there is a large disturbed area in which the spots are breaking down and re-forming, so that on one day it appears to have three concentrations, the next day two, and on the third day three concentrations again, but not in the same relative positions as they were on the first day. Should these be counted as three groups the first day, two the second, and three the third? Probably so, but after six years of observing sunspots I cannot tell you with assurance. On these matters you must develop your own sense of judgment.

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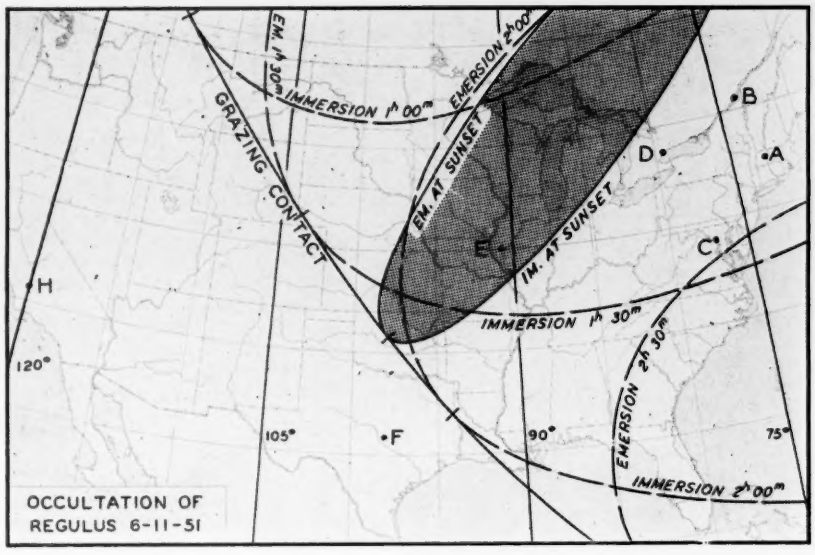


The occultation path of Regulus, June 10-11, drawn by Paul W. Stevens.

OCCULTATIONS IN JUNE

REGULUS will be occulted on the evening of June 10-11, for observers in Canada and the eastern half of the United States, as shown in the accompanying chart prepared by Paul W. Stevens, of the Rochester Astronomy Club. The six-day moon will be well located in the evening sky, and earthshine will render visible the dark part of the moon.

In the north central states, Regulus will be occulted before sunset, but its brightness and high altitude should make it possible to observe immersion in a 4-inch telescope. Farther east, the occultation takes place after the sun is gone, with immersion on the Atlantic Coast in deep twilight. For an intermediate zone, shaded on the map, the sun will set while Regulus is behind the lunar disk. This should be the best region to time both contacts, because twilight will mask the moon's glare and make it easiest to observe emersion at the bright limb. Serious timing of occultations requires accuracy to 1/10 second; information on this kind of observing may be had from Mrs. Margaret W. Beardsley, R.F.D. 1, Springfield, Vt.

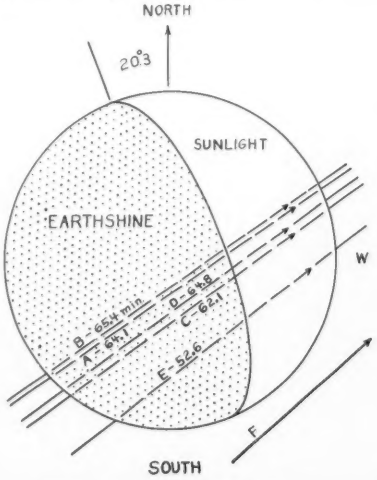


Diagram by Paul W. Stevens.

The effect of the strong southeasterly direction of the shadow path is seen on the second chart, showing Regulus' path behind the moon, plotted for the standard stations. Such places as station **F**, in Texas, will observe a close conjunction of the star and the moon.

It has also been noticed by Mr. Stevens that the star Kappa Geminorum should be occulted on June 7-8 for observers at other stations in the East than just those for which predictions are listed. He would be interested in receiving reports from observers in order to determine the region in which grazing contact with the star takes place.

June 7-8 **Kappa Geminorum** 3.7, 7:41.5 +24-31.0, 3, Im: **B** 1:39.4 +0.4 −1.8 126; **D** 1:45.0 +0.4 −2.0 135; **E** 1:58.9 +0.7 −2.6 158. Em: **E** 2:39.1 −0.4 −0.8 245.

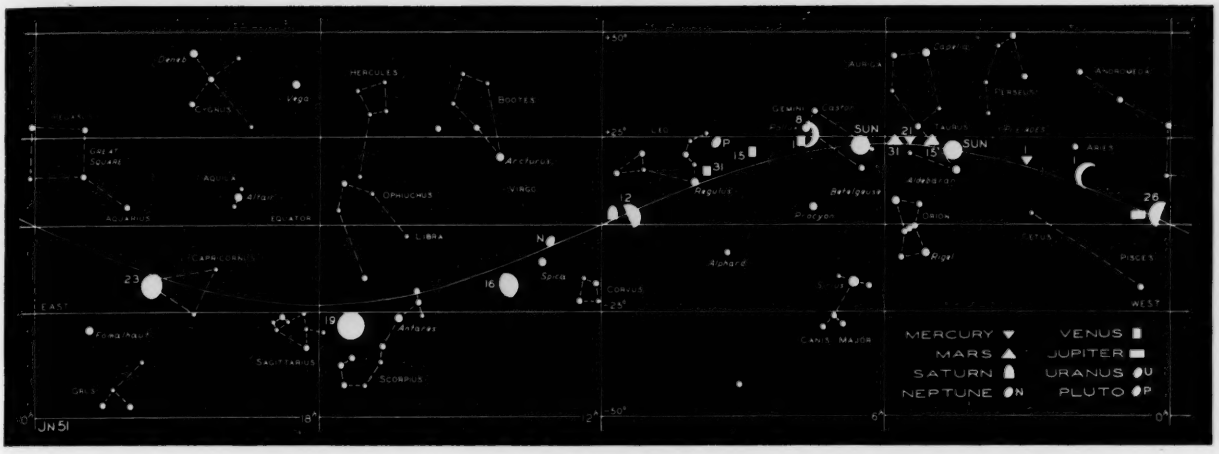
June 10-11 **Alpha Leonis, Regulus** 1.3, 10:05.8 +12-12.5, 6, Im: **A** 1:20.5 −0.5 −2.1 135; **B** 1:13.4 −0.5 −2.1 133; **C** 1:26.5 −0.4 −2.3 147; **D** 1:14.5 −0.5 −2.3 143; **E** 1:20.1 0.0 −3.0 170. Em: **A** 2:24.6 −0.3 −1.8 291; **B** 2:18.8 −0.4 −1.9 294; **C** 2:28.6 −0.6 −1.6 282; **D** 2:19.3 −0.6 −1.7 286; **E** 2:12.7 −1.6 −1.2 263.

June 22-23 **Delta Capricorni** 3.0, 21:44.3 −16-21.0, 18, Im: **A** 4:40.7 −0.9 +1.8 55. Em: **A** 5:49.6 −1.4 +1.4 254; **B** 5:52.3 −1.3 +1.3 257; **C** 5:38.5 −1.3 +1.5 251; **D** 5:42.6 −1.1 +1.4 258.

July 23-24 **Delta Piscium** 4.6, 0:46.1 +7-19.1, 19, Im: **A** 7:09.9 −1.1 +1.9 54; **C** 6:58.4 −0.9 +2.0 52; **E** 6:52.2 −0.3 +2.2 32; **F** 6:30.7 −0.2 +2.1 38. Em: **A** 8:25.7 −1.3 +1.7 228; **B** 8:29.2 −1.3 +1.5 235; **C** 8:13.5 −1.3 +1.8 229; **D** 8:18.4 −1.4 +1.6 241; **E** 7:56.6 −1.3 +1.6 255; **F** 7:34.0 −1.0 +1.6 251; **G** 7:42.5 ... ... 307.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, data from the American Ephemeris and the British Nautical Almanac are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, a and b quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The a and b quantities tabulated in each case



are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computations of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo — LoS**), and multiply **b** by the difference in latitude (**L — LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5, +42°.5	**E**	+91°.0, +40°.0
B	+73°.6, +45°.6	**F**	+98°.0, +31°.0
C	+77°.1, +38°.9	**G**	+114°.0, +50°.9
D	+79°.4, +43°.7	**H**	+120°.0, +36°.0
		I	+123°.1, +49°.5

MINIMA OF ALGOL

June 1, 23:00; 4, 19:48; 7, 16:37; 10, 13:26; 13, 10:15; 16, 7:04; 19, 3:52; 22, 0:41; 24, 21:30; 27, 18:18; 30, 15:07. July 3, 11:56; 6, 8:45.

These predictions are geocentric (corrected for the equation of light), based on observations made in 1947. See **Sky and Telescope**, Vol. VII, page 260, August, 1948, for further explanation.

VARIABLE STAR MAXIMA

June 2, T Columbae, 7.6, 051533; 6, X Centauri, 7.8, 114441; 7, X Ophiuchi, 6.9, 183308; 10, S Ursae Majoris, 7.9, 123961; 12, RT Sagittarii, 7.9, 201139; 14, R Serpentis, 6.8, 154615; 17, RS Scorpii, 6.8, 164844; 27, R Phoenicis, 7.8, 235150; 29, Omicron Ceti (Mira), 3.7, 021403; 30, RS Librae, 7.7, 151822. July 2, R Ursae Majoris, 7.6, 103769; 5, T Cephei, 5.8, 210868; 7, T Centauri, 6.1, 133633.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the predicted magnitude, and the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern).

PHASES OF THE MOON

New moon	June	4, 16:40
First quarter	June	12, 18:52
Full moon	June	19, 12:36
Last quarter	June	26, 6:21
New moon	July	4, 7:48

		Distance	Diameter
	June		
Apogee	6, 1h	252,600 mi.	29′ 24″
Perigee	19, 14h	221,800 mi.	33′ 29″
	July		
Apogee	3, 4h	252,600 mi.	29′ 24″

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury will be located west of the sun for most of June. It may be glimpsed the first few days of the month rising one hour before sunrise, and of zero magnitude. On June 25th it is in superior conjunction with the sun.

Venus attains greatest elongation on June 25th, 45° 25′ east of the sun in longitude. The dazzling planet travels from a position 5° south of Pollux on June 1st into Leo by the end of the month. On the night of June 12-13, Venus crosses the northern edge of the Beehive cluster in Cancer. Telescopically, Venus will then present a disk 21″ in diameter, appearing 56 per cent illuminated.

Earth arrives at heliocentric longitude 270° on June 22nd at 5:25 UT. Summer commences in the Northern Hemisphere and winter in the Southern.

Mars, located a few degrees west of the sun, remains unobservable during June.

Jupiter rises after midnight, and will be the only planet in the sky till dawn. Located in Pisces, Jupiter greatly outshines all nearby stars and cannot be mistaken.

Saturn comes to eastern quadrature with the sun on June 17th, and therefore sets about midnight local time. Moving slowly eastward, Saturn does not appear conspicuous in western Virgo, for it is of +1.3 magnitude. The rings of Saturn still command special attention; they are inclined 1°.2 to our line of sight.

Uranus cannot be viewed, for it is only a short distance east of the sun.

Neptune may be observed before midnight in the western sky. The planet will be virtually motionless ½° west of Theta Virginis, appearing of the 8th magnitude.

E. O.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

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WANTED: RFT ocular, elliptical diagonals ⅞″ x 1¼″, 1⅝″ x 2¼″ (must be flat). Will trade 1/6″ Tolles ocular. W. Williams, Culver, Ind.

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NORTON'S "Star Atlas and Reference Handbook," latest edition, 1950, $5.25 postpaid. "Atlas Celeste," International Astronomical Union's official atlas to magnitude 6.0, $2.55. "Bonner Durchmusterung," moon maps, and other foreign publications. Ask for information. Herbert A. Luft, 42-10 82nd St., Elmhurst, N. Y.

FOR SALE: Mounted 5″ and 6″ refractor objectives of first quality, $200.00 and $300.00. Edged blanks, $45.00, $32.50, $22.50. Correspondence invited. Earl Witherspoon, Sumter, S. C.

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of June, respectively.

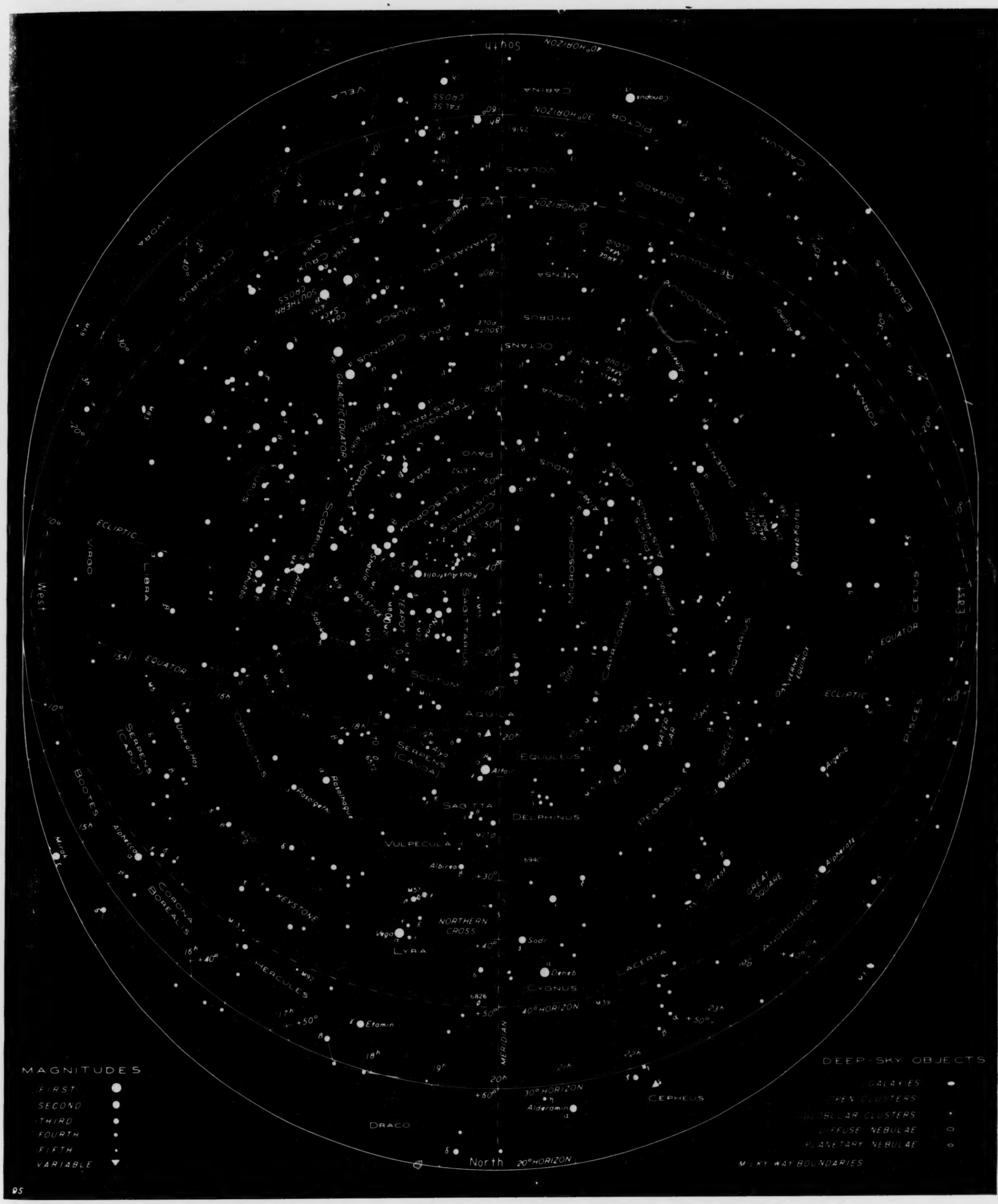
STARS FOR JUNE

BETWEEN the times of last month's chart and this one the north pole of the galaxy crosses the meridian, passing practically through the overhead point for observers in the southern United States. As the equator of the galaxy nearly coincides with the central line of the Milky Way as we see it from the earth, the Milky Way now stretches completely around the heavens close to the horizon.

Although the general region around the galactic pole contains fewer stars, both bright and faint, than do areas along the Milky Way, these skies are nevertheless populated with some interesting and easy-to-learn constellations. For example, Bootes is a kite-shaped figure that contains the sixth brightest star in the sky, Arcturus, orange colored, and quickly located by continuing the curve formed by stars in the handle of the Big Dipper.

Corona Borealis, the Northern Crown, is an unmistakable semicircle of stars next to Bootes. Its brightest star is Alphecca.

Three famous globular clusters make easy hunting for small telescopes in this region: M3, in Canes Venatici; M5, in Serpens Caput, and M13, in Hercules. M5, NGC 5904, as photographed with the 200-inch telescope recently, is pictured on our back cover this month.



The sky as seen from latitudes 20° to 40° south, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of September, respectively.

SOUTHERN STARS

WHAT makes a striking constellation? Obviously, some characteristic arrangement of stars is necessary, but perhaps it is more important that the range in magnitude of the principal stars be not too great. Scorpius and Sagittarius may be examined as they pass high in the sky for southern observers. Neither has a "pat" geometrical pattern, such as a triangle, square, or circlet shape, but their bright stars are arranged in a smooth sequence that leaves no difficult blank spots such as occur in some other constellations.

The first 14 stars in Sagittarius range only from visual magnitude 1.95 for Kaus Australis (ε) to 4.01 for Mu (μ). Only eight of these are needed to form the familiar Teapot for northern observers, and they range through only 1½ magnitudes. Of course, the colors of these stars make some difference in how bright they appear to the eye; in the Teapot four stars are blue or white, and four are orange, of spectral type **K0**.

Not counting Antares (magnitude 1.23), the 14 stars required to form Scorpius' head, body, and sting range only from magnitude 1.71 for Lambda (λ) to 3.44 for Eta (η). Most are blue-white, as they form part of the Scorpius-Centaurus concentration of hot stars.